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STANDARDIZATION TASK REPORT
TASK NO. 5

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ESTABLISHMENT OF STANDARDIZATION DATA FOR MONEL AND K-MONEL FASTENERS

Conducted for:
Department of the Navy
Bureau of Ships

Contract No. NObs-90493

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Conducted by: E. Goodman
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Approved by: H. P. Weinberg
H. P. Weinberg, Director
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Alexandria, Virginia

I PURPOSE

The purpose of this task is to standardize a method for assuring proper bolt tension. Prestressing experiments are to include three of the methods described in Handbook H28, Part III, pages 52-53, namely, the micrometer, torque measurement, and angular turn of the nut methods. Both through bolting and set-stud bolting assemblies are to be investigated. The effect of different thicknesses of the material being clamped on the three methods of determining preload are to be investigated.

II MATERIALS TESTED

A. Requirements:-

1. K-Monel Studs - K-monel studs used in the performance of this task must conform to Military Standard MS18116 and the applicable requirements of specifications QQ-N-286 and MIL-B-857.

2. Monel Studs - Monel studs used in the performance of this task must conform to the applicable requirements of QQ-N-281 and MIL-B-857, except that the studs must have the following mechanical properties:

Tensile strength - 80,000 psi, minimum

Yield strength - 40,000 psi, minimum (0.2 percent offset)

Elongation in 2 inches - 20 percent, minimum

3. Plate Materials - Plate materials must conform to the following specifications.

Material	Specification
High Tensile Steel Plate (HTS)	MIL-S-16113 Grade HT
HY80 Steel Plate	MIL-S-16216
Cast HY80 Steel	MIL-S-23008
Cast Monel	QQ-N-288
Valve Bronze	MIL-B-16541A

4. <u>Porosity</u> - All cast materials must be subjected to radiographic examination to ascertain freedom from porosity.

B. <u>Actual Chemical and Mechanical Properties</u>:-

Tables I and II are a compilation of the required and actual chemical composition and mechanical properties, respectively, of the studs and materials used for tests performed in this task.

All cast materials were subjected to radiographic examination. The valve bronze and cast HY80 were found to be free from porosity. Several plates of cast monel had an area of porosity which was marked so that no holes were drilled and tapped in these areas.

Table I Chemical Composition

Material	Item	C	Si	Mn	Cr	Ni	Cu	Fe	Mo	Cb	S	Al	Ti	Pb	V	P
Monel Studs (Cut Threads)	Required	0.3 max	.5 max	2.0 max	-	63-67	Bal.	2.5 max	-	-	.024 max	.5 max	-	-	-	-
	1/2"Studs	.14	.10	.93	-	64.21	33.03	1.56	-	-	.010	-	-	-	-	-
	7/8"Studs	.15	.19	.90	-	64.80	33.14	.79	-	-	.005	-	-	-	-	-
	1-1/8"Studs	.15	.10	1.13	-	64.12	33.84	.63	-	-	.005	-	-	-	-	-
K-Monel (Cut Threads)	Required	.25 max	1.0 max	1.5 max	-	63-70	Bal.	2.0 max	-	-	.010 max	2.0-4.0	.25-1.00	-	-	-
	1/2"Studs	.16	.10	.55	-	64.80	30.46	.60	-	-	.005	2.79	.51	-	-	-
	7/8"Studs	.16	.10	.55	-	64.80	30.46	.60	-	-	.005	2.79	.51	-	-	-
	1-1/8"Studs	.23	.11	.53	-	65.75	29.66	.56	-	-	.005	2.70	.43	-	-	-
Monel Studs (Rolled Threads)	Required	0.3 max	.5 max	2.0 max	-	63-67	Bal.	2.5 max	-	-	.024 max	.5 max	-	-	-	-
	K20-2A 1/	.144	.18	.84	.65	66.30	30.54	1.84	-	-	.018	.04	.05	.010	-	-
	K20 2/	.082	.12	.85	.03	65.54	31.28	1.91	-	-	.015	.05	.06	.009	-	-
	Q32-2A	.17	.09	.88	-	66.20	31.58	1.05	-	-	.007	.007	-	.007	-	-
	Q32-3A	.16	.13	.85	-	65.62	32.31	.90	-	-	.006	.015	-	-	-	-
	Q32-5HF	.17	.09	.88	-	66.20	31.58	1.05	-	-	.007	-	-	-	-	-
	Q32-5ONF	.19	.19	.90	-	64.58	32.84	.127	-	-	.010	.017	-	-	-	-
	S38 3/	.121	.16	.99	.13	64.61	32.31	1.59	-	-	.010	.04	.04	.006	-	-
K-Monel Studs (Rolled Threads)	Required	.25 max	1.0 max	1.5 max	-	63-70	Bal.	2.0 max	-	-	.010 max	2.0-4.0	.25-1.00	-	-	-
	K20-2A, 5HF	.19	.11	.57	-	65.62	29.60	.64	-	-	.007	2.77	.47	-	-	-
	K20-3A, 5ONF	.21	.22	.57	-	64.54	30.26	1.01	-	-	.005	2.76	.40	-	-	-
	Q32 3/	.13	.12	.68	-	65.00	29.99	.66	-	-	.005	2.89	.50	-	-	-
	S38 3/	.18	.14	.58	-	64.84	30.15	.62	-	-	.005	2.96	.50	-	-	-
Monel Casting	Required	.35 max	2.00 max	1.5 max	-	62-68	26-33	2.5 max	-	-	-	-	-	-	-	-
	Actual	.24	1.97	.96	-	63.2	31.01	1.22	-	1.40	-	-	-	-	-	-
HY80 Steel Casting	Required	.2 max	.50 max	.55-.75	1.35-1.65	2.50-3.25	.2 max	-	.30-.60	-	.015 max	-	.02 max	-	.03 max	.020 max
	Actual 3/	.18	.28	.62	1.60	3.10	.15	-	.49	-	.006	-	.004	-	.01	.005
Valve Bronze	Required	-	-	-	-	1.00 max	86.0-89.0	0.25 max	-	-	-	-	-	1.0-2.0	-	.05 max
	Actual	-	-	-	-	.85	87.69	.09	-	-	.032	-	-	1.46	-	.013

1/ Refers to sizes listed in Military Standard MS15991.
2/ For size K20 studs having setting end thread classes 3A, 5HF and 5ONF.
3/ Sn: Required - 5.5-6.5 Actual - 5.23 Zn: Required - 3.0-5.0 Actual - 4.03
3/ All studs of this size.

<u>Table II Mechanical Properties</u>

Material	Item	Tensile Strength (psi)	Yield Strength (psi)	Elongation in 2"(%)
Monel Studs (Cut Threads)	Required	80,000 min.	40,000 min.	20.0 min.
	All 1/2" Studs	106,500	102,000	23.0
	All 7/8" Studs	95,500	83,000	30.0
	All 1-1/8" Studs	90,500	77,000	31.0
K-Monel Studs (Cut Threads)	Required	130,000 min.	90,000 min.	20.0 min.
	All 1/2" Studs	178,700	148,200	20.3
	All 7/8" Studs	163,000	119,100	23.4
	All 1-1/8" Studs	151,500	107,200	24.2
Monel Studs (Rolled Threads)	Required	80,000 min.	40,000 min.	20.0 min.
	K20-2A 1/	92,300	80,100	23.3
	K20-3A	98,500	88,700	21.0
	K20-5HF	98,500	88,750	21.0
	K20-5ONF	86,000	65,000	23.8
	Q32-2A	96,200	73,700	29.2
	Q32-3A	100,200	77,300	27.3
	Q32-5HF	92,700	58,700	26.5
	Q32-5ONF	96,900	71,300	32.1
	S38 2/	81,200	56,300	33.7
K-Monel Studs (Rolled Threads)	Required	130,000 min.	90,000 min.	20.0 min.
	K20-2A	146,300	99,100	26.4
	K20-3A	143,600	99,100	26.6
	K20-5HF	146,300	99,100	26.4
	K20-5ONF	156,200	98,900	23.7
	Q32 2/	153,000	96,300	23.1
	S38 2/	152,700	91,600	28.4
Monel Casting	Required	65,000 min.	32,500 min.	25 min.
	Actual	78,400	39,900	45.0
HY80 Steel Casting	Required	For information only	80,000-95,000	20.0 min.
	Actual	113,000	92,000	22.5
Valve Bronze	Required	34,000 min.	-	22.0 min.
	Actual	40,600	-	42.5

1/ Refers to sizes listed in Military Standard MS15991.
2/ All studs of this size.

III THREAD GAGING

The thread major diameter, minor diameter, pitch diameter, included angle and thread lead of each stud and bolt used in this program were measured at threee points along the thread. An average of the three results for each dimension was used. The major diameter was measured on a Pratt & Whitney Super Micrometer. Tri-roll gages were used to measure the pitch diameter to an accuracy of 0.0001 inch. The included angle, minor diameter and lead were measured on a J & L Comparator to an accuracy of 0.0001 inch.

The bolts and the nut end of the studs had UNC class 2A threads in accordance with Handbook H28, Screw-Thread Standards for Federal Services.

IV TEST PROCEDURE

To accurately relate angular turn of the nut, applied torque, and bolt elongation to actual bolt tension, a bolt-tension calibrator must be used. A Skidmore-Wilhelm Torque Tension Tester was used in this program to measure induced bolt tension (Figure A). A schematic drawing of this apparatus is shown in Figure B. The bolt to be tested is put through the shoulder (see Figure B) and then through the cover and the nut engaged. The initial length of the bolt is measured and then the nut tightened to a predetermined torque. The torque, angular turn of the nut, and elongation are recorded and the nut tightened to the next level. In set-stud bolting the shoulder is threaded and the setting end of the stud engaged into it. The nut end of the stud is put through the cover and the nut engaged.

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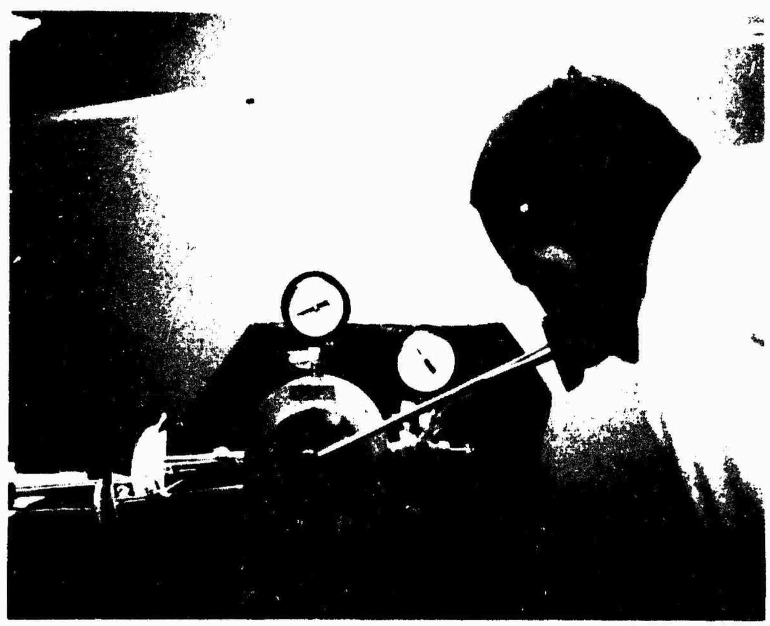


FIGURE 4: Skidmore-Wilhelm Torque Tension Tester

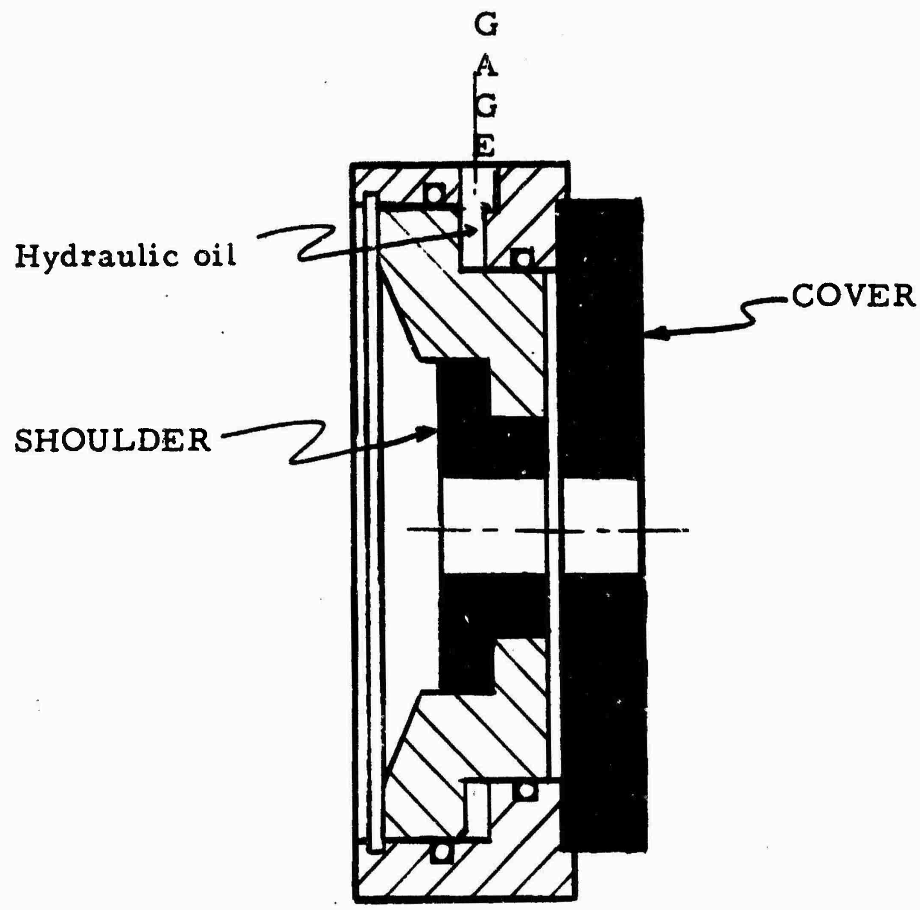


FIGURE B: Skidmore-Wilhelm Torque Tension Tester

Testing:

The following are the test parameters used in this prestress task.

1. Bolt and Stud Materials

   a. Monel

   b. K-monel

2. Shoulder and Cover Materials (see Figure B).

   a. High Tensile Steel (HTS)

   b. HY80

   c. Cast HY80

   d. Cast Monel

   e. Valve Bronze

3. <u>Shoulder and Cover Thicknesses</u> -

The following are thicknesses of materials being clamped for each size bolt and stud. For through bolting the total thickness is the sum of the shoulder and cover thickness.

a. For through bolting:

<u>For 1/2 inch bolts</u> -

(1)	Shoulder - 2 inches	Cover - 1-1/8 inches
and (2)	Shoulder - 9/16 inch	Cover - 9/16 inch

<u>For 7/8 inch bolts</u> -

(1)	Shoulder - 1-1/8 inches	Cover - 1-1/8 inches
and (2)	Shoulder - 2 inches	Cover - 9/16 inch

<u>For 1-1/8 inch bolts</u> -

(1)	Shoulder - 1-1/8 inches	Cover - 1-1/8 inches

b. For set-stud bolting:

(1) 9/16 inch*

(2) 1-1/8 inches

(3) 2 inches

*Not used with 7/8 and 1-1/8 inch studs since high prestress caused buckling.

For set-stud bolting the setting end of the stud was engaged in the shoulder and the above three cover thicknesses tested.

4. <u>Nut</u> -

Self-locking nuts in accordance with MS17828 were used throughout this task.

5. <u>Washer</u> -

No washer was used in these prestress tests.

6. <u>Plating</u> -

Bolts, studs and nuts were not plated.

7. <u>Lubrication</u> -

Nuts: Nuts were used as received from the manufacturer.

Bolts and studs: Bolts and studs were vapor degreased in trichloroethylene and lubricated with "3-in-One" SAE 20 oil.

8. <u>Torqued Member</u> -

The nut was torqued in all of the prestress tests.

9. <u>Nut Seating to Begin Angular Turn</u> -

The original plan was to begin measuring angular turn of the nut at 100 inch-pounds torque or 10 percent of the ultimate torque rating shown on MS17828, whichever was smaller. The torque at which to begin angular turn, however, must be greater than the torque to engage the nut on the bolt at no preload. Therefore, the following torques had to be used as the starting point for measuring angular turn of the nut to assure seating of the self-locking nut.

Size (inches)	Torque to Start Measuring Angular Turn of the Nut
1/2	120 in-lbs.
7/8	30 ft-lbs.
1-1/8	30 ft-lbs.

10. <u>Effective Length of Bolts and Studs</u> -

The effective lengths (See Handbook H28, Part III, Appendix 12, Method 1, page 52) of the bolts and studs for each of the bolted joints tested are shown in Table III.

Table III Effective Length of Bolts and Studs

BOLT	Size (inches)	Shoulder thickness (inches)	Cover thickness (inches)		Effective length (inches) Clamped Material HY80	HTS	Monel	Cast HY80
	1/2	9/16	9/16	Thread	.85	.87	.78	.77
				Shank	1.04	1.04	1.04	1.04
	1/2	2	1-1/8	Thread	1.03	.98	.98	.83
				Shank	2.86	2.86	2.86	2.86
	7/8	1-1/8	1-1/8	Thread	.94	.90	.89	.80
				Shank	2.10	2.10	2.10	2.10
	7/8	2	9/16	Thread	1.23	1.21	1.18	1.04
				Shank	2.10	2.10	2.10	2.10
	1-1/8	1-1/8	1-1/8	Thread	1.53	1.49	1.48	1.39
				Shank	1.60	1.60	1.60	1.60
STUD	1/2	1-1/8	9/16	Thread	1.61	1.62	1.58	1.56
				Shank	-	-	-	-
	1/2	1-1/8	1-1/8	Thread	2.44	2.44	2.44	2.29
				Shank	.5	.5	.5	.5
	1/2	1-1/8	2	Thread	2.79	2.76	2.77	2.56
				Shank	1.02	1.02	1.02	1.02
	7/8	1-1/8	1-1/8	Thread	2.47	2.46	2.43	2.33
				Shank	-	-	-	-
	7/8	1-1/8	2	Thread	2.64	2.64	2.64	2.48
				Shank	.3	.3	.3	.3
	1-1/8	1-1/2	1-1/8	Thread	2.49	2.49	2.50	2.40
				Shank	-	-	-	-
	1-1/8	1-1/2	2	Thread	2.36	2.33	2.33	2.22
				Shank	1.0	1.0	1.0	1.0

V RESULTS

Prestress vs. Angular Turn of the Nut and Prestress vs. Applied Torque data are plotted in Figures 1 through 48. The data from which these curves were plotted are included in the Appendix. Figures 49 through 53 are a plot of Prestress vs. Elongation for representative combinations of stud material, size and length and clamped material and thickness.

Plotted points are actual measurements made during the tests and the curves were obtained from the following formula.

$$e = \frac{(F/A_u)\,L_u}{E} + \frac{(F/A_t)\,L_t}{E}$$

where
e = Total bolt or stud elongation, in.
F = Preload, lbs
A_u = Cross-sectional area of unthreaded portion, in^2
A_t = Equivalent tensile stress area of threads, in^2
L_u = Length of unthreaded portion, in.
L_t = Effective length of threaded portion, in.
E = Modulus of elasticity, psi

There appears to be good agreement between experimental and calculated values. In each figure, each curve denotes the results for clamping a different shoulder and cover material. The following was used to designate the data for each material.

- ⊡ HTS
- ▽ HY80
- △ Cast HY80
- ✕ Monel
- ⊙ Valve Bronze

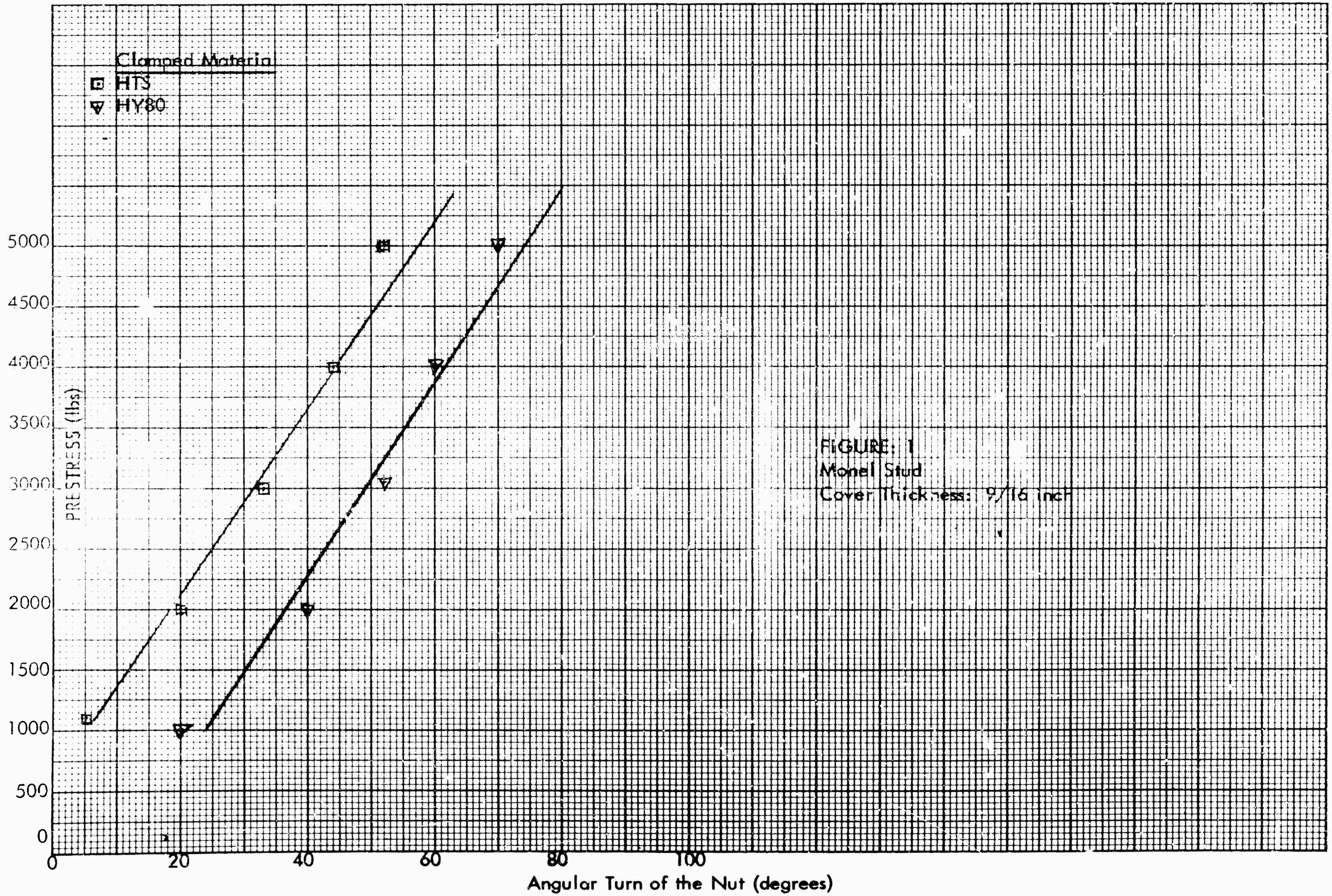


FIGURE: 1
Monel Stud
Cover Thickness: 9/16 inch

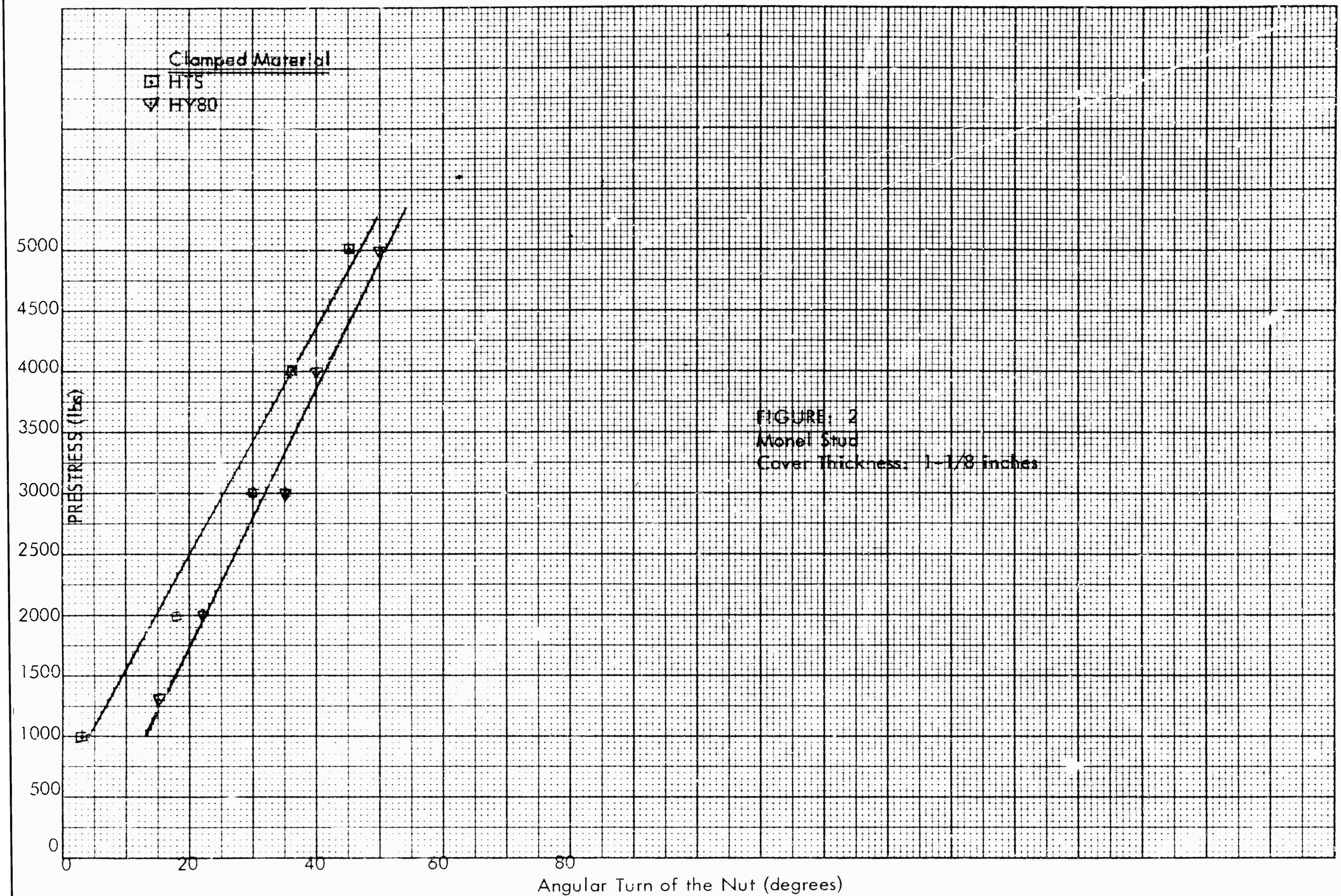
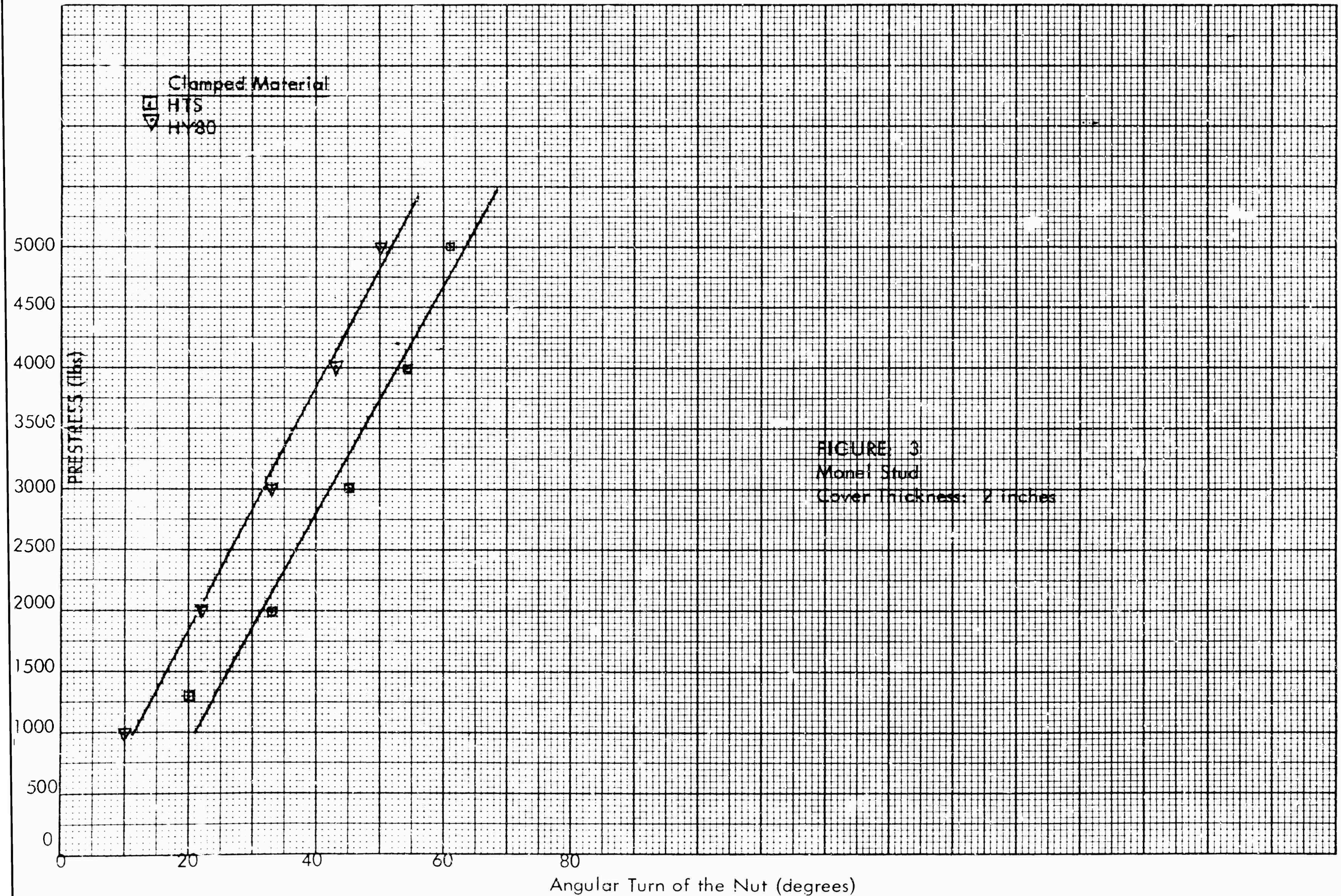


FIGURE: 2
Monel Stud
Cover Thickness: 1-1/8 inches



Clamped Material
HTS
HY80
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
PRESTRESS (lbs)
0
20
40
60
80
Angular Turn of the Nut (degrees)
FIGURE: 3
Monel Stud
Cover Thickness: 2 inches

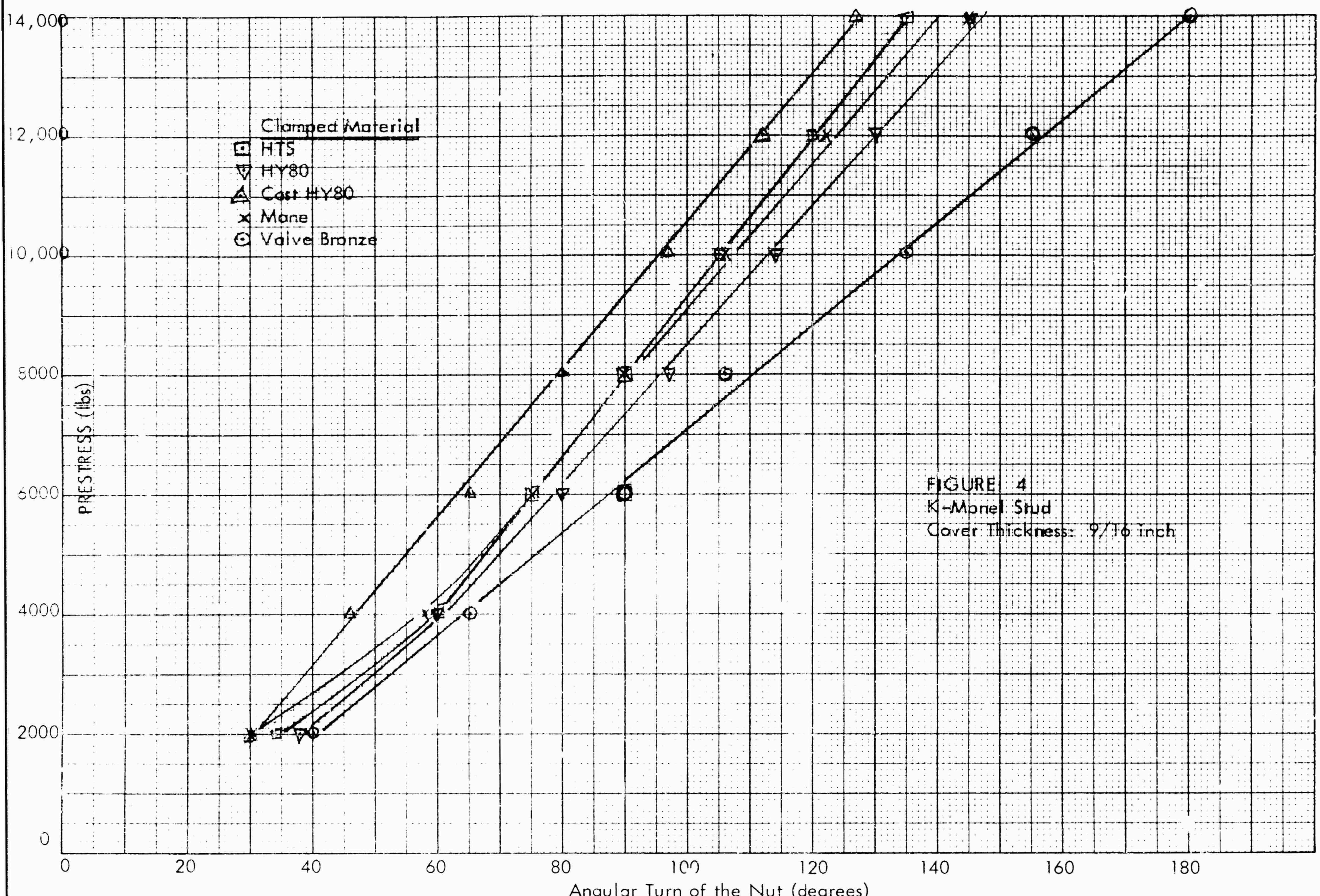


FIGURE 4
K-Monel Stud
Cover Thickness: 9/16 inch

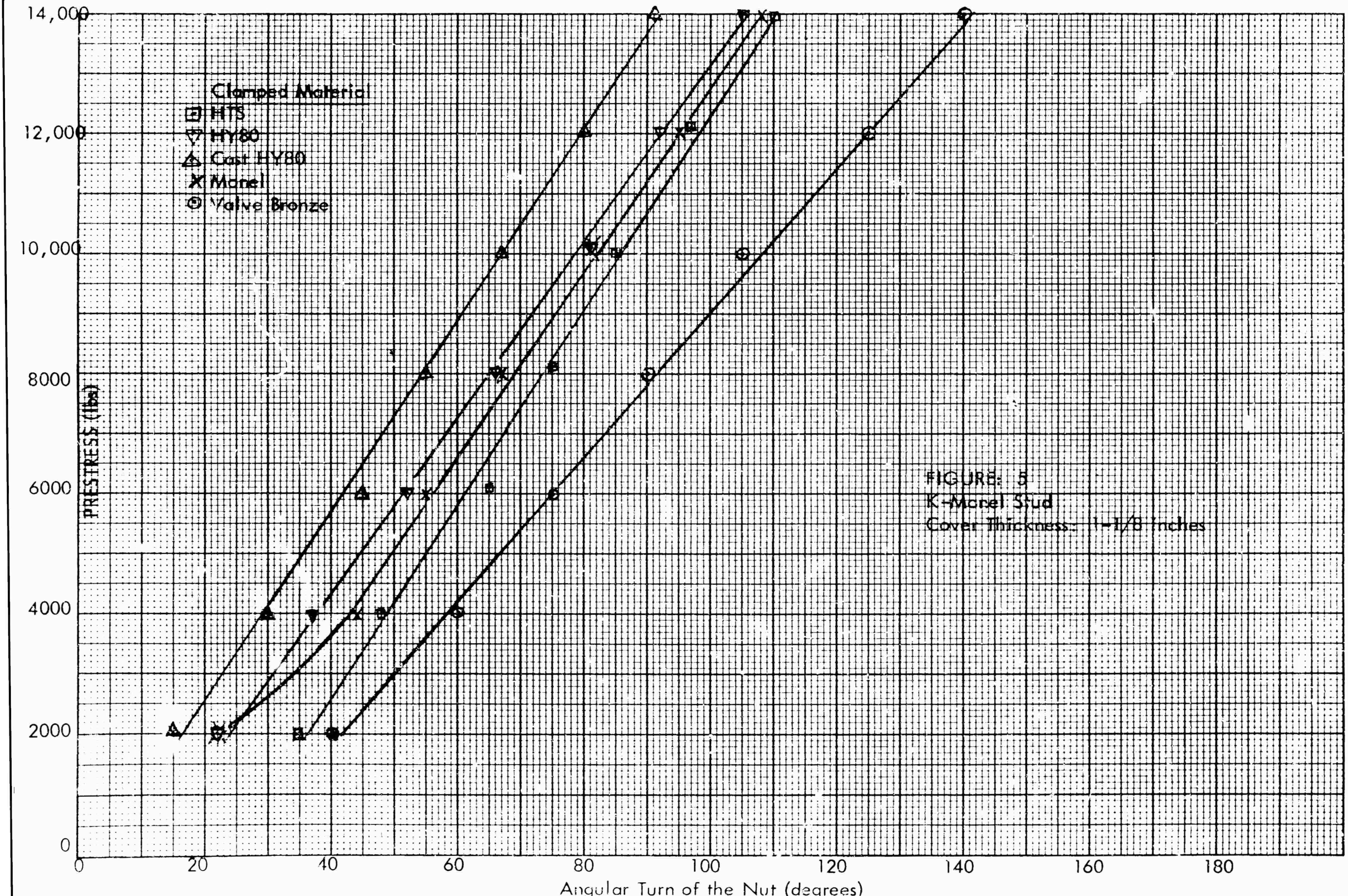


FIGURE: 5
K-Monel Stud
Cover Thickness: 1-1/8 Inches

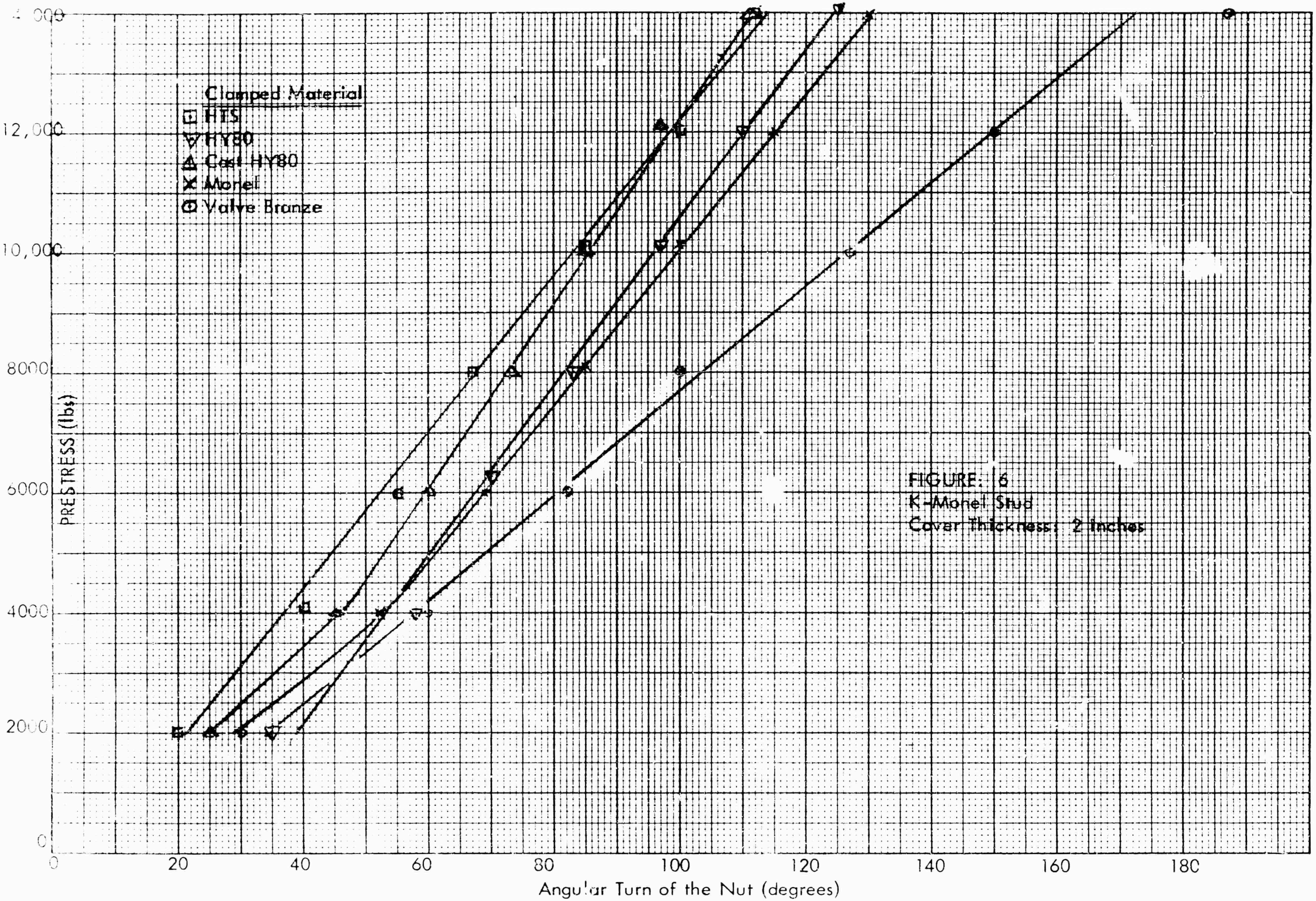


FIGURE: 6
K-Monel Stud
Cover Thickness: 2 Inches

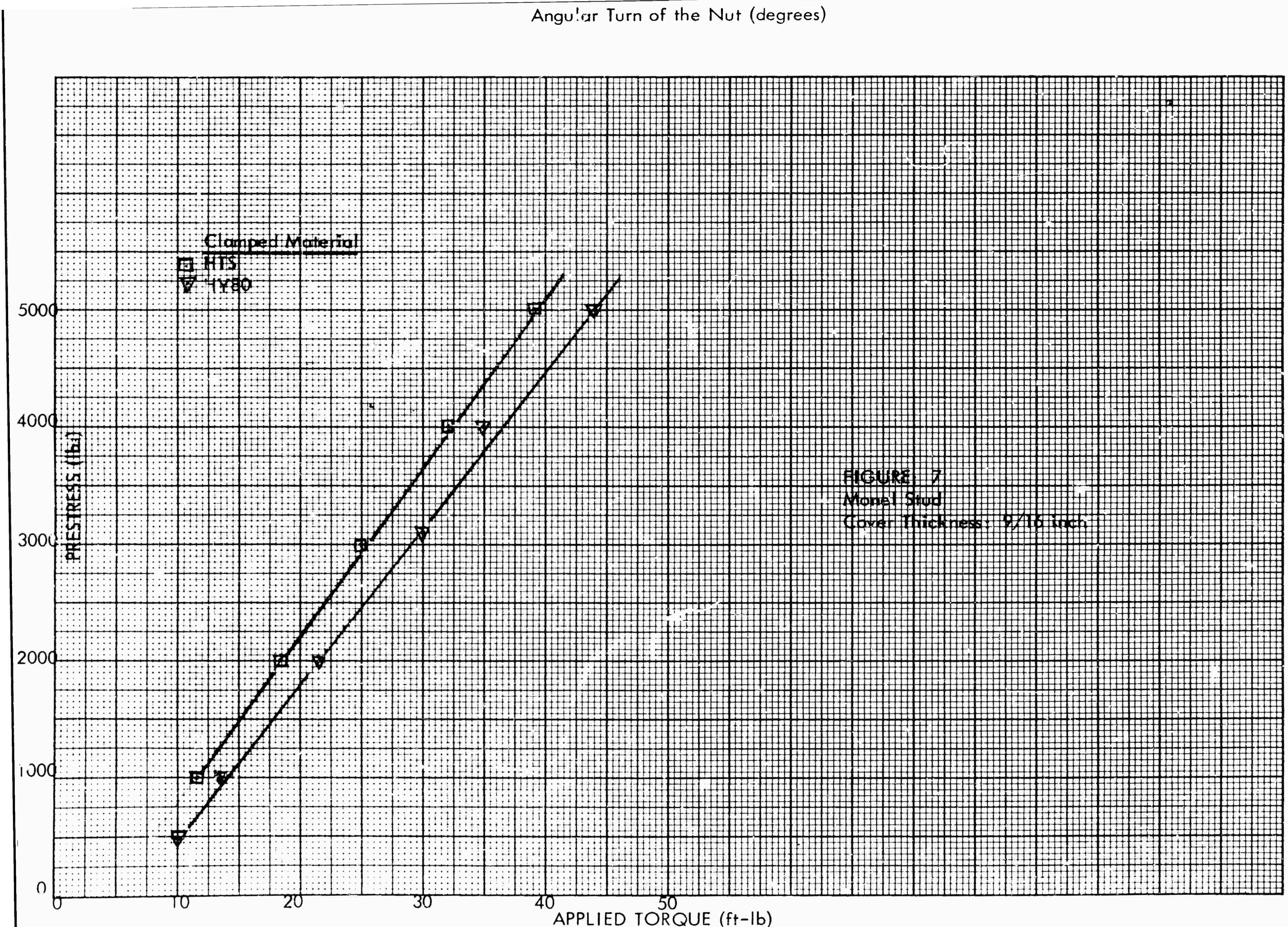


FIGURE 7
Monel Stud
Cover Thickness: 9/16 inch

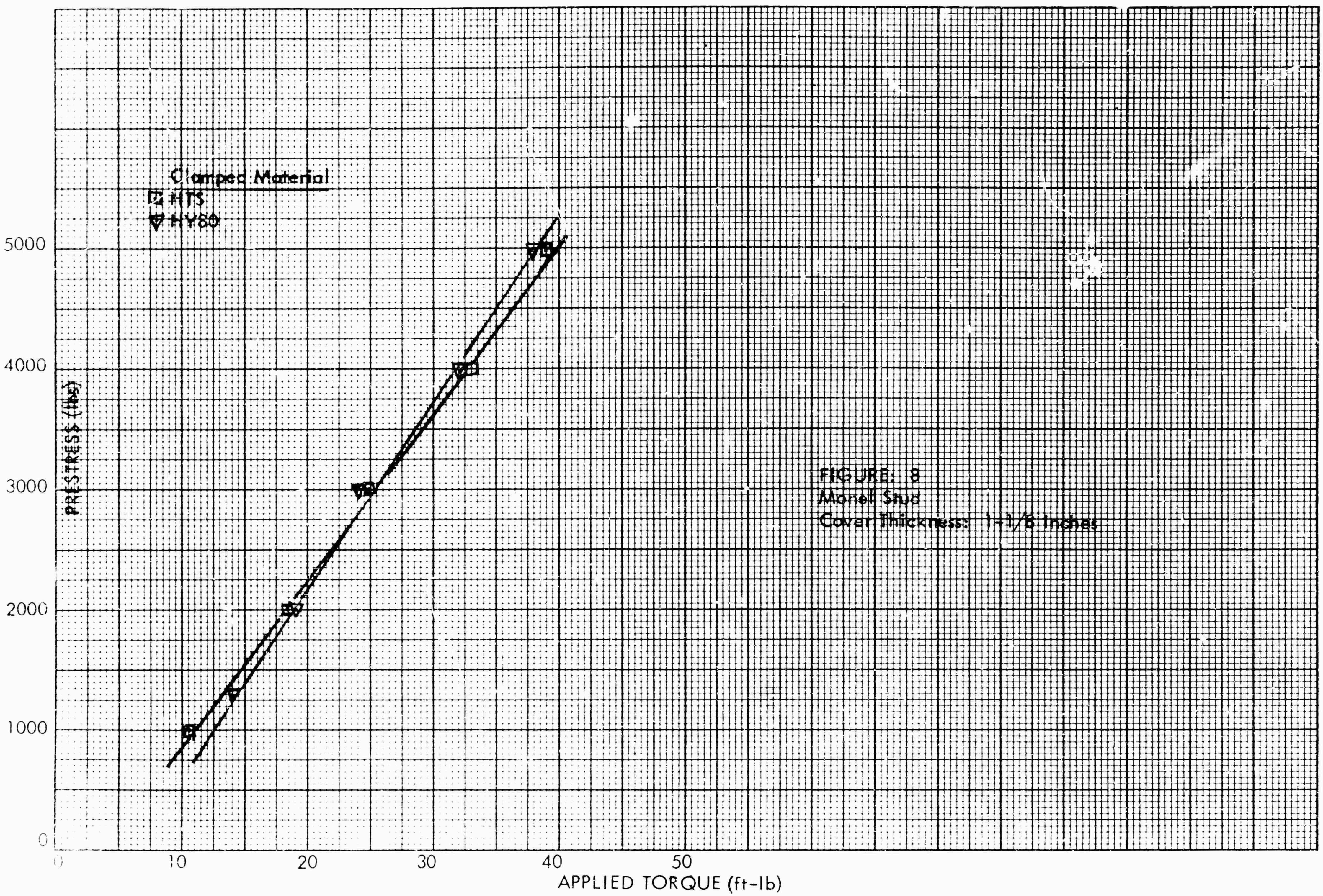


FIGURE: 8
Monell Stud
Cover Thickness: 1-1/8 Inches

APPLIED TORQUE (ft-lb)

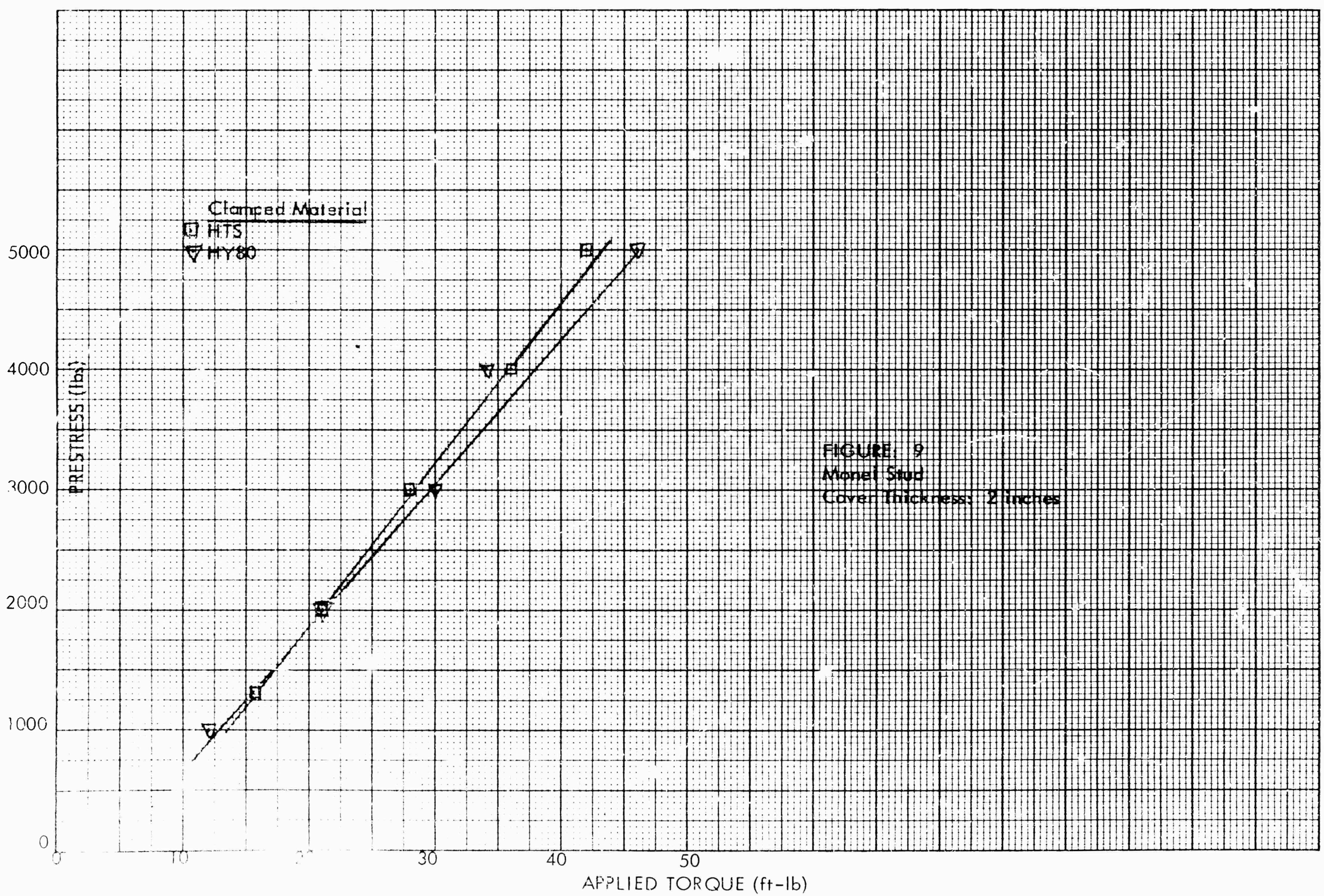
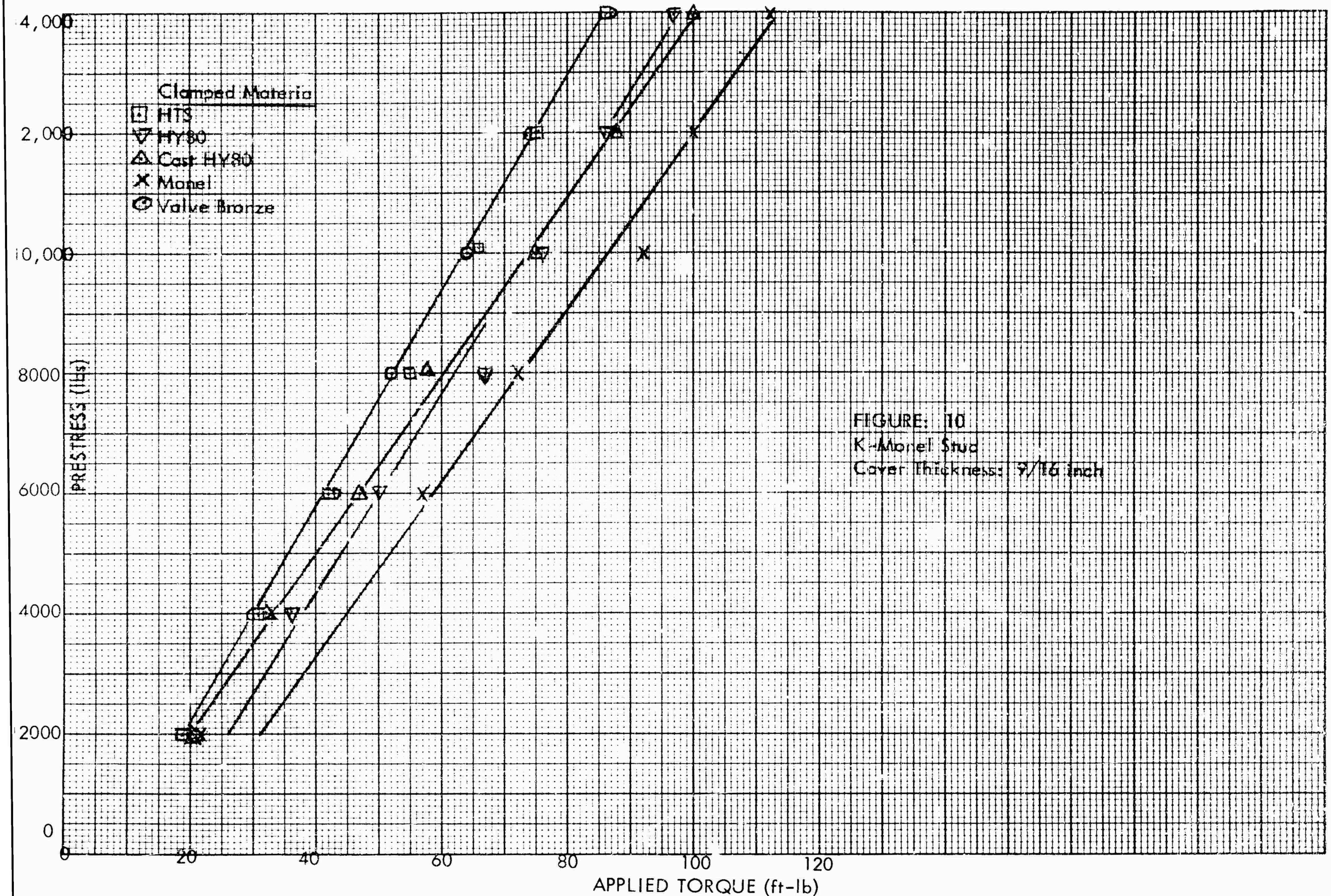


FIGURE 9
Monel Stud
Cover Thickness: 2 inches


Clamped Materia
HTS
HY80
Cast HY80
Monel
Valve Bronze
FIGURE: 10
K-Monel Stud
Cover Thickness: 9/16 inch
PRESTRESS (lbs)
APPLIED TORQUE (ft-lb)
4,000
2,000
10,000
8000
6000
4000
2000
0
20
40
60
80
100
120

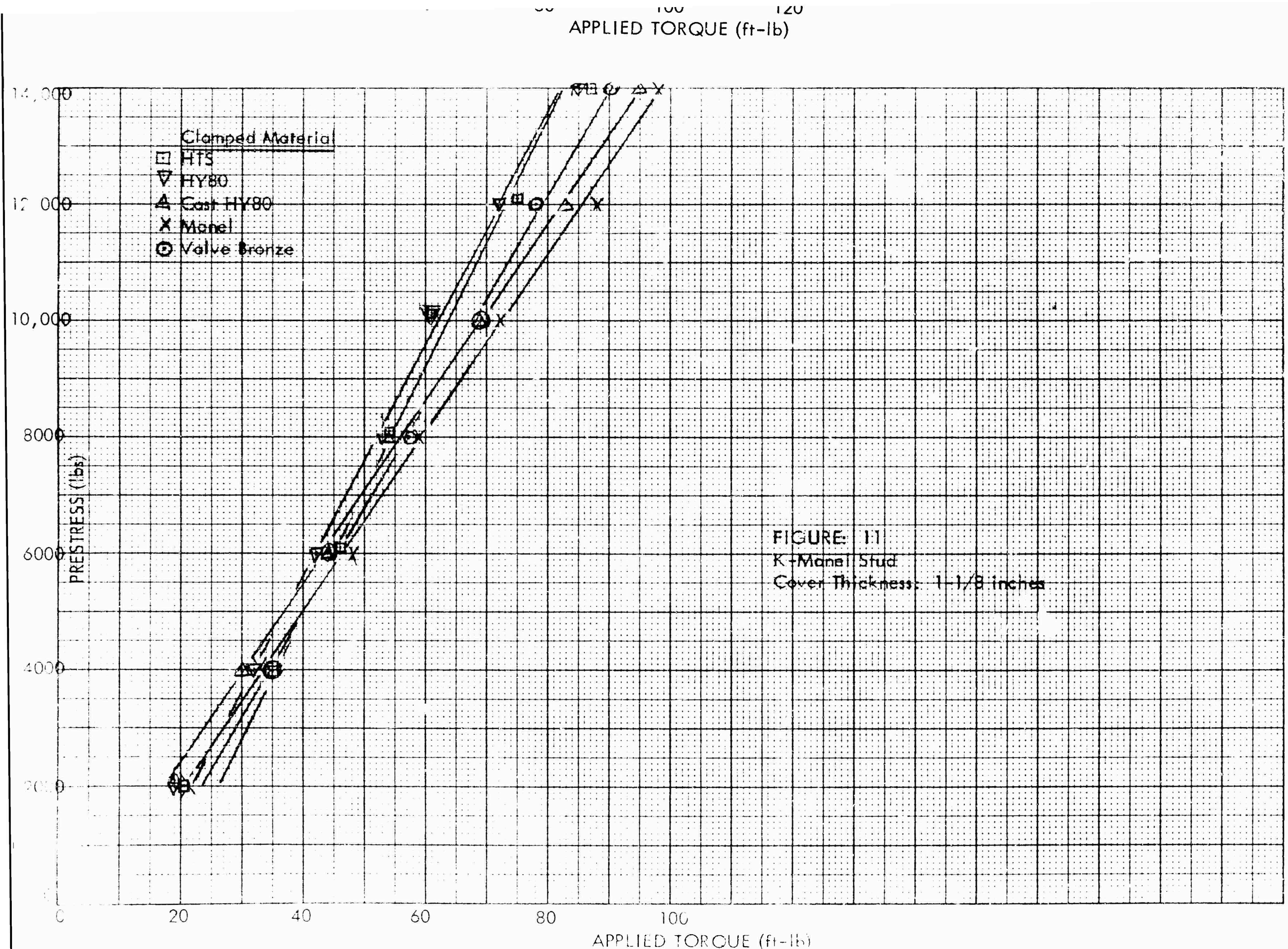
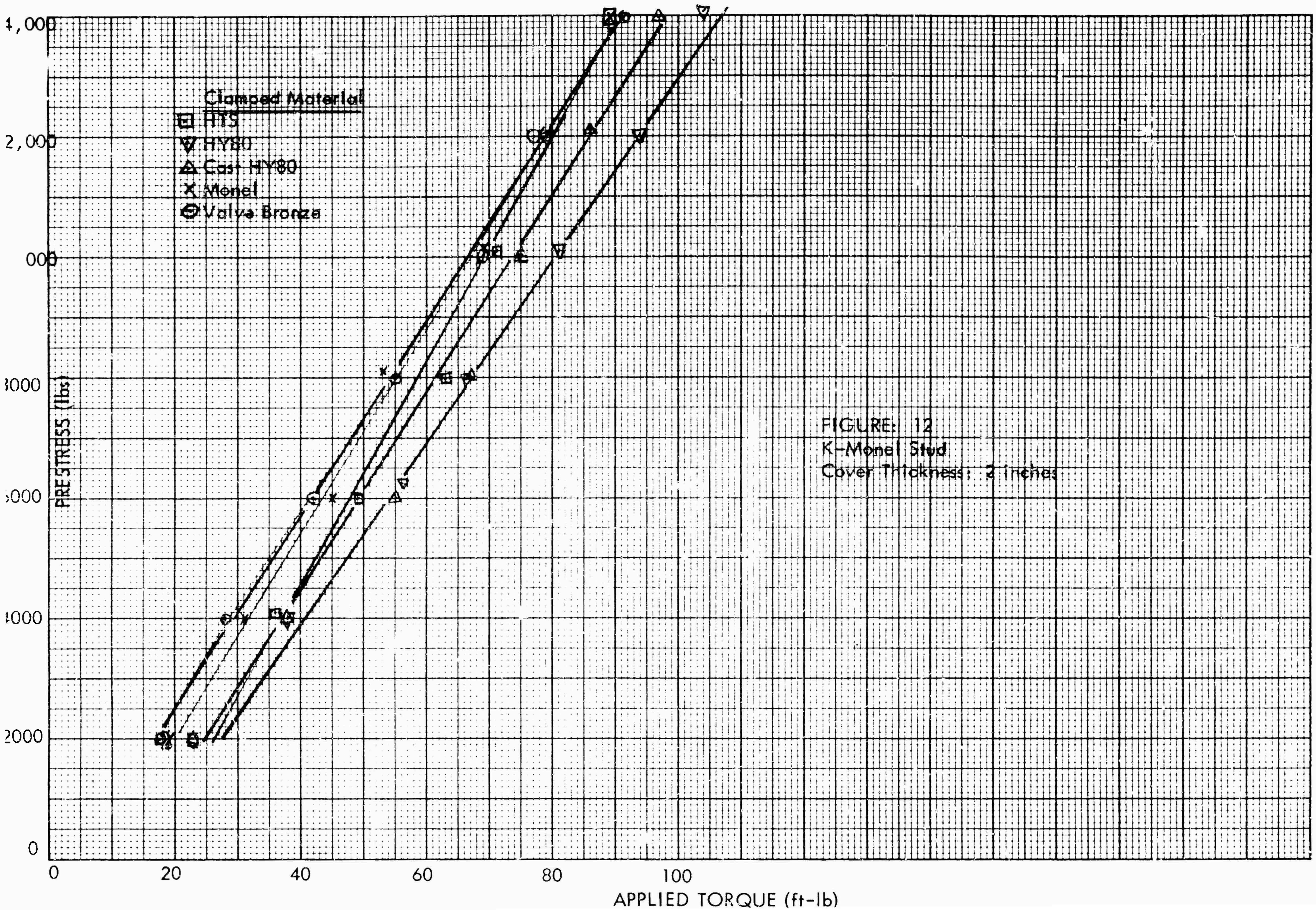


FIGURE: 11
K-Monel Stud
Cover Thickness: 1-1/8 inches


Clamped Material
HTS
HY80
Cast HY80
Monel
Valve Bronze
FIGURE: 12
K-Monel Stud
Cover Thickness: 2 inches
PRESTRESS (lbs)
APPLIED TORQUE (ft-lb)
0
20
40
60
80
100
2000
3000
4000
5000
6000

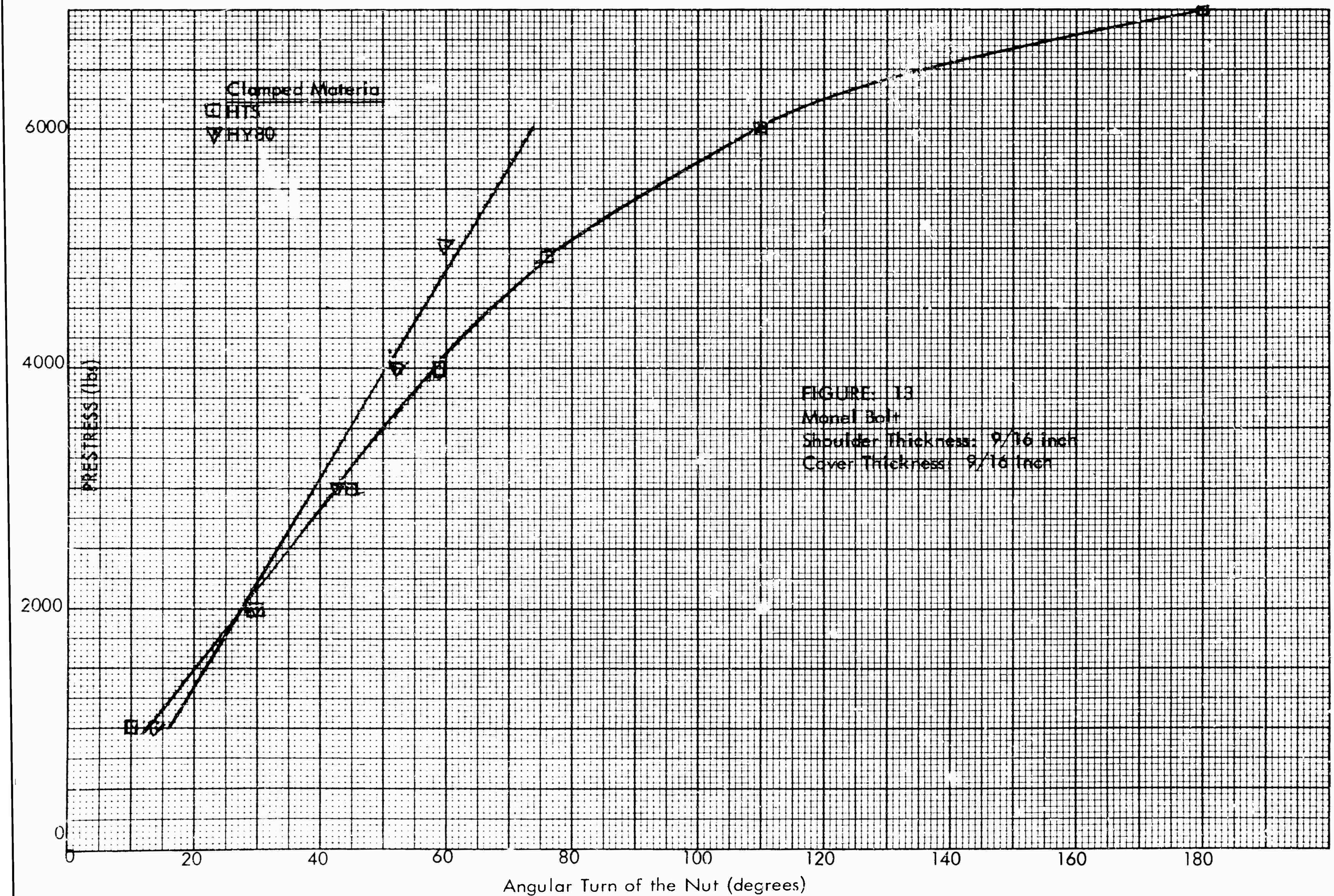
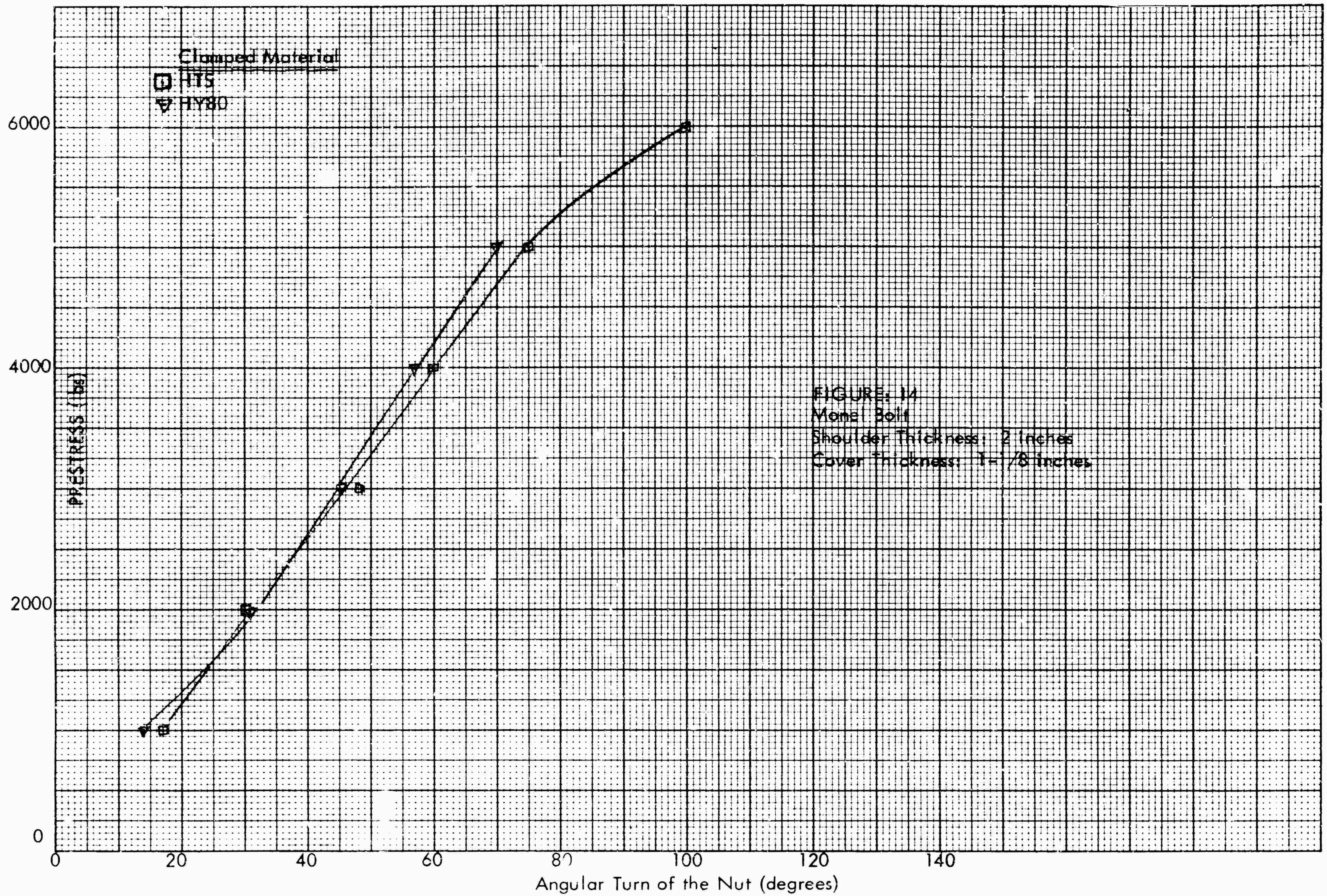
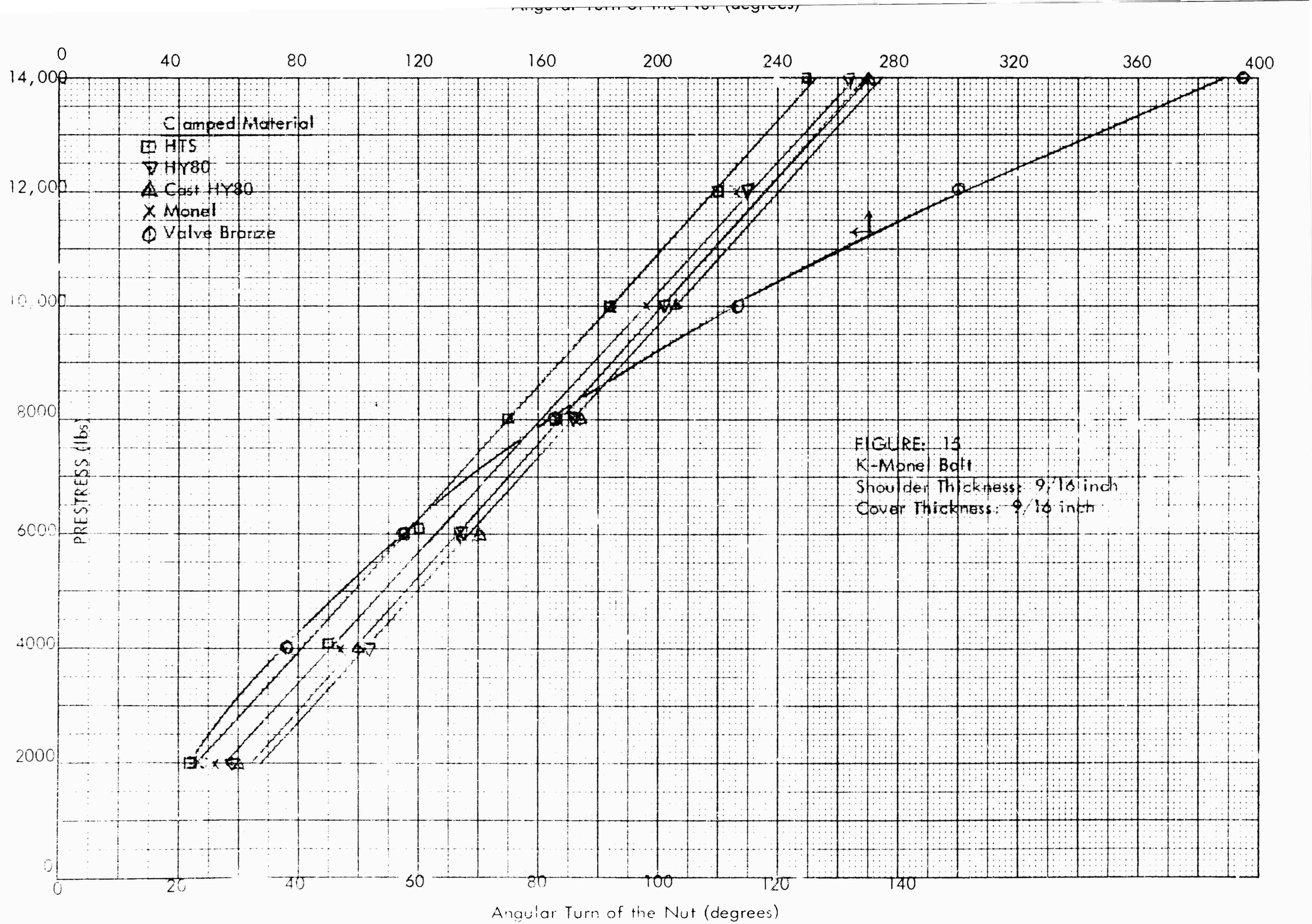
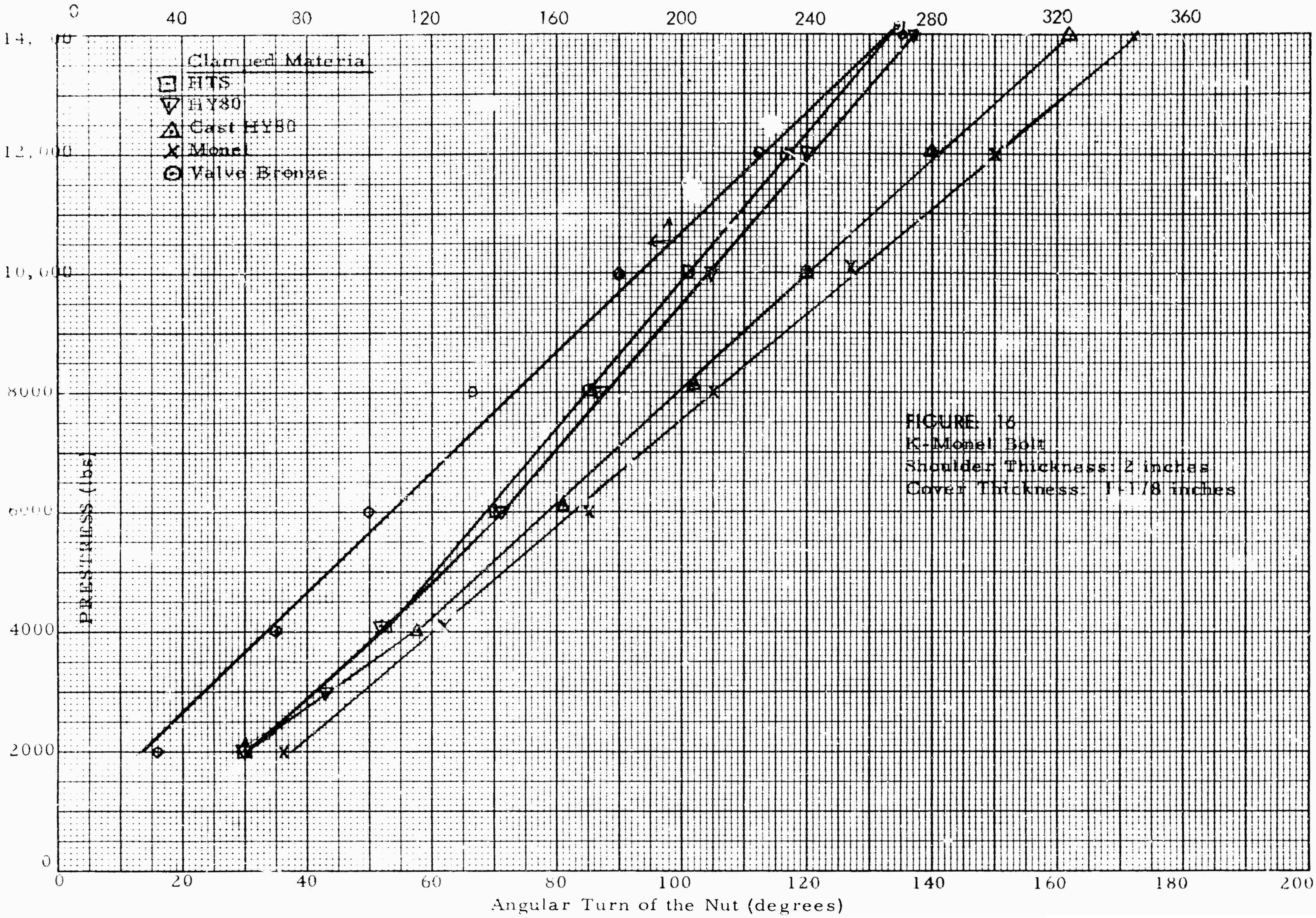


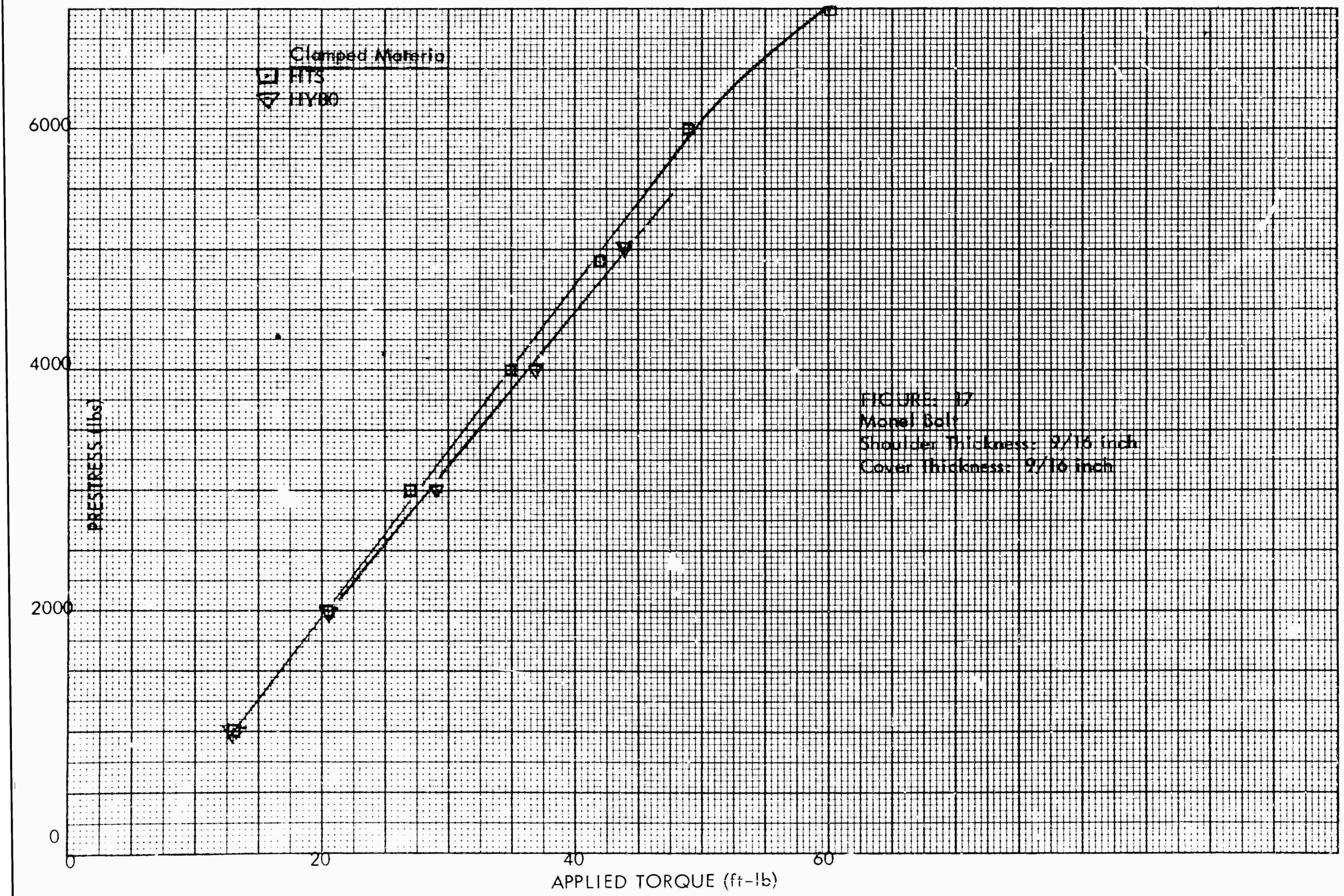
FIGURE: 13
Monel Bolt
Shoulder Thickness: 9/16 inch
Cover Thickness: 9/16 inch


Clamped Material
HTS
HY80
6000
4000
2000
0
PRESTRESS (lbs)
0
20
40
60
80
100
120
140
Angular Turn of the Nut (degrees)
FIGURE: 14
Monel Bolt
Shoulder Thickness: 2 Inches
Cover Thickness: 1-1/8 Inches



Angular Turn of the Nut (degrees)
0
40
80
120
160
200
240
280
320
360
400
14,000
12,000
10,000
8000
6000
4000
2000
0
PRESTRESS (lbs)
Clamped Material
HTS
HY80
Cast HY80
Monel
Valve Bronze
FIGURE: 15
K-Monel Bolt
Shoulder Thickness: 9/16 inch
Cover Thickness: 9/16 inch
20
60
100
140
Angular Turn of the Nut (degrees)


Clamped Materia
HTS
HY80
Cast HY80
Monel
Valve Bronze
FIGURE 16
K-Monel Bolt
Shoulder Thickness: 2 inches
Cover Thickness: 1-1/8 inches
PRESTRESS (lbs)
Angular Turn of the Nut (degrees)
0
20
40
60
80
100
120
140
160
180
200
0
40
80
120
160
200
240
280
320
360
0
2000
4000
6000
8000
10,000
12,000


Clamped Materia
HTS
HY80
6000
4000
2000
0
PRESTRESS (lbs)
0
20
40
60
APPLIED TORQUE (ft-lb)
FIGURE: 17
Monel Bolt
Shoulder Thickness: 9/16 inch
Cover Thickness: 9/16 inch

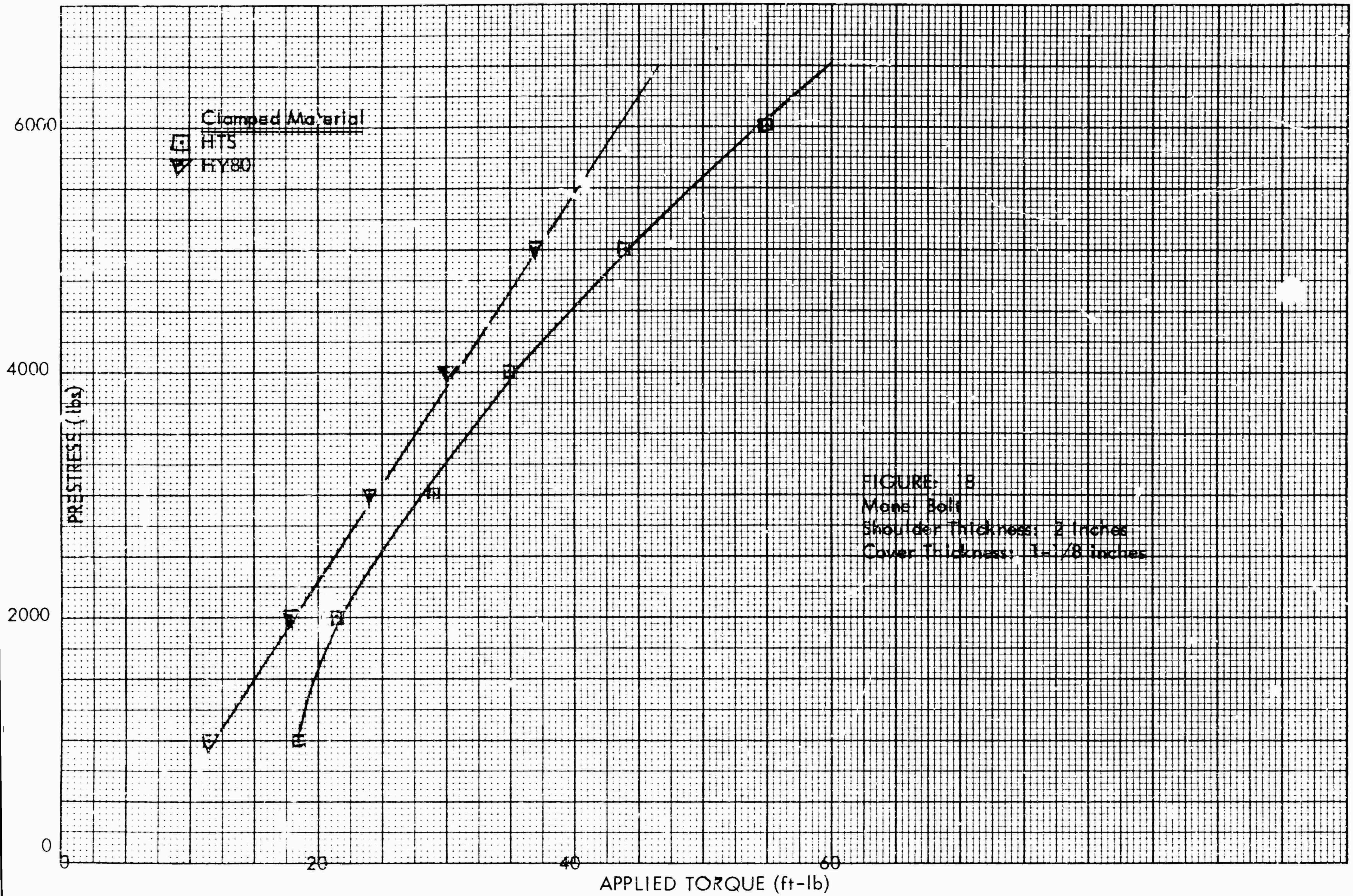
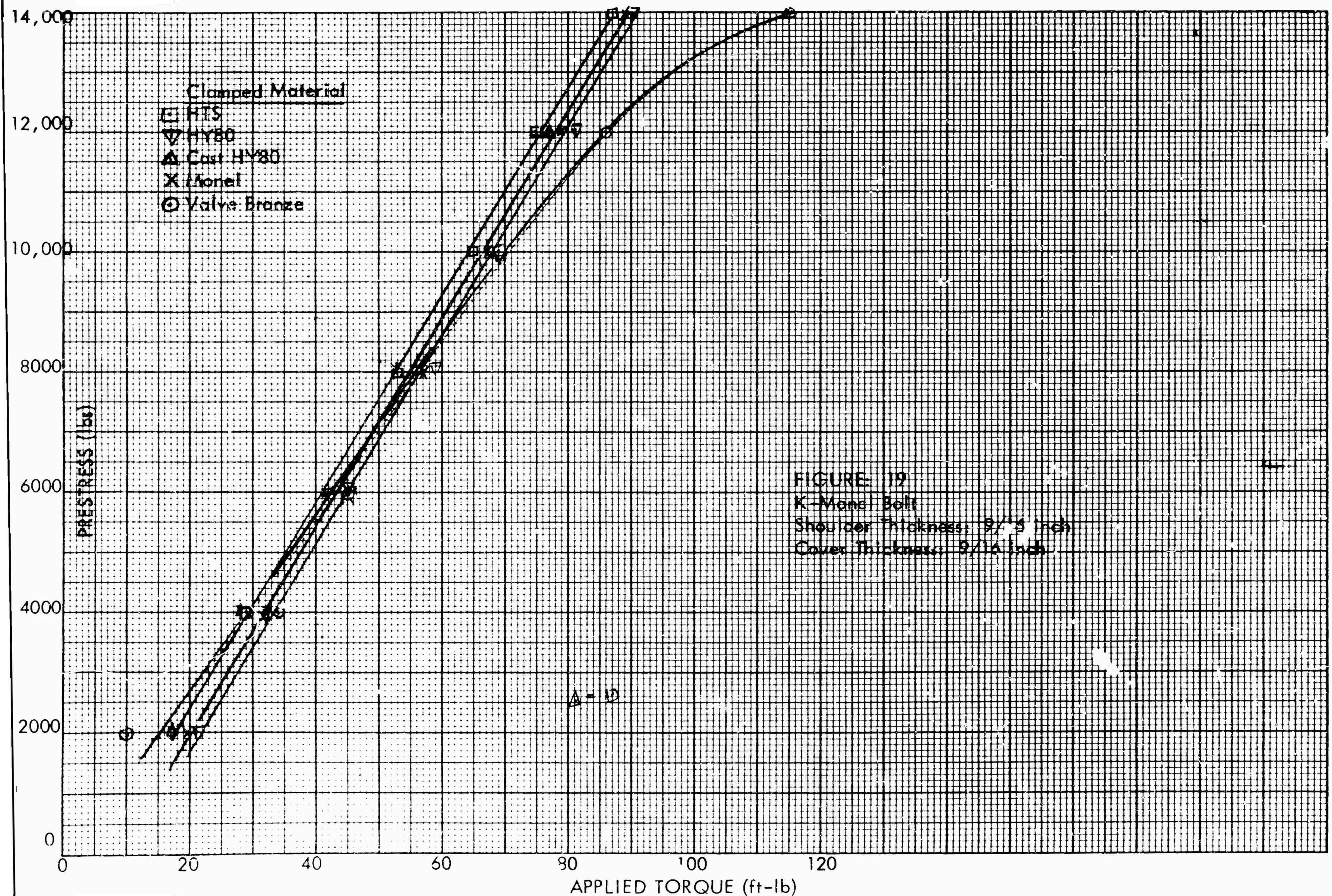
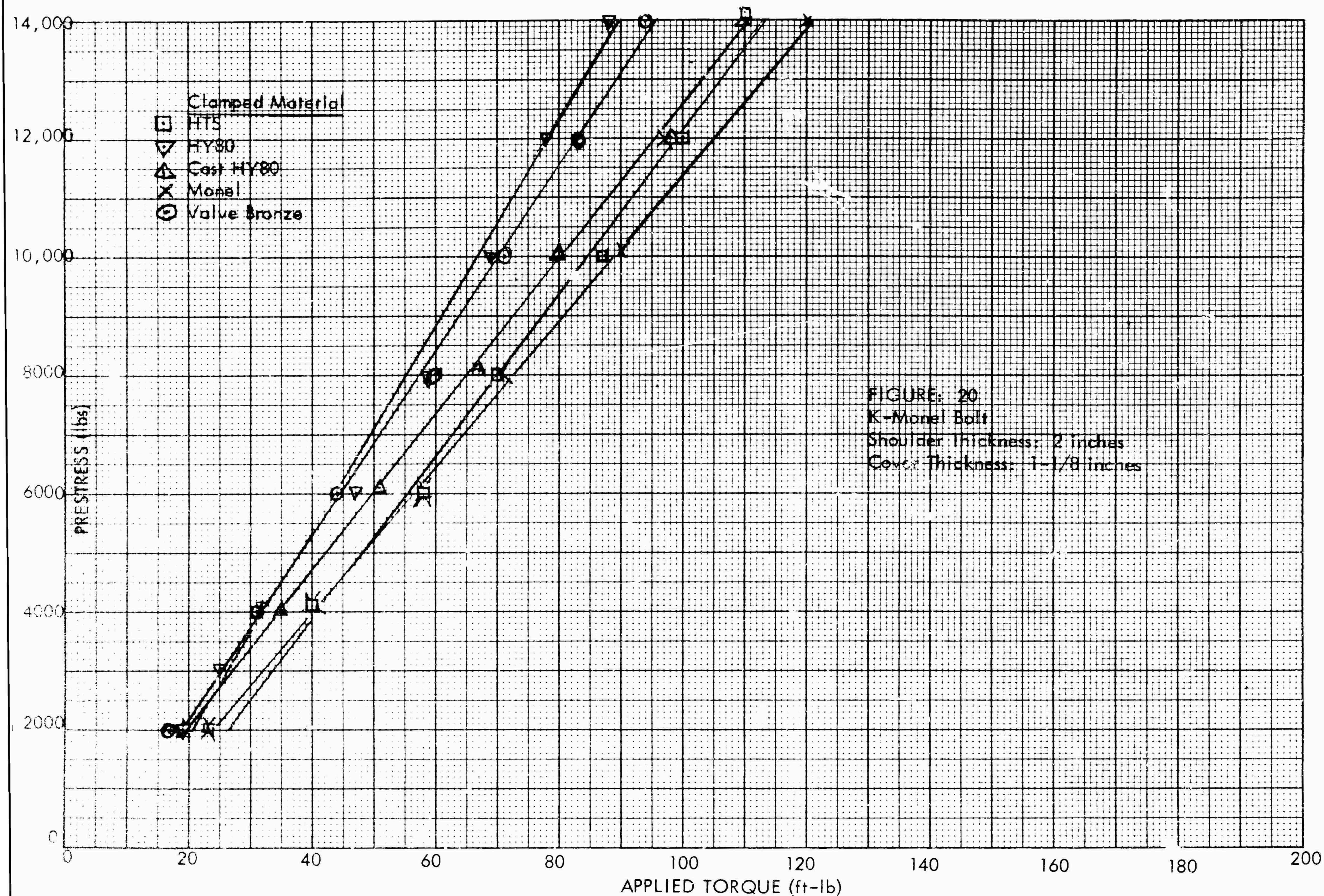
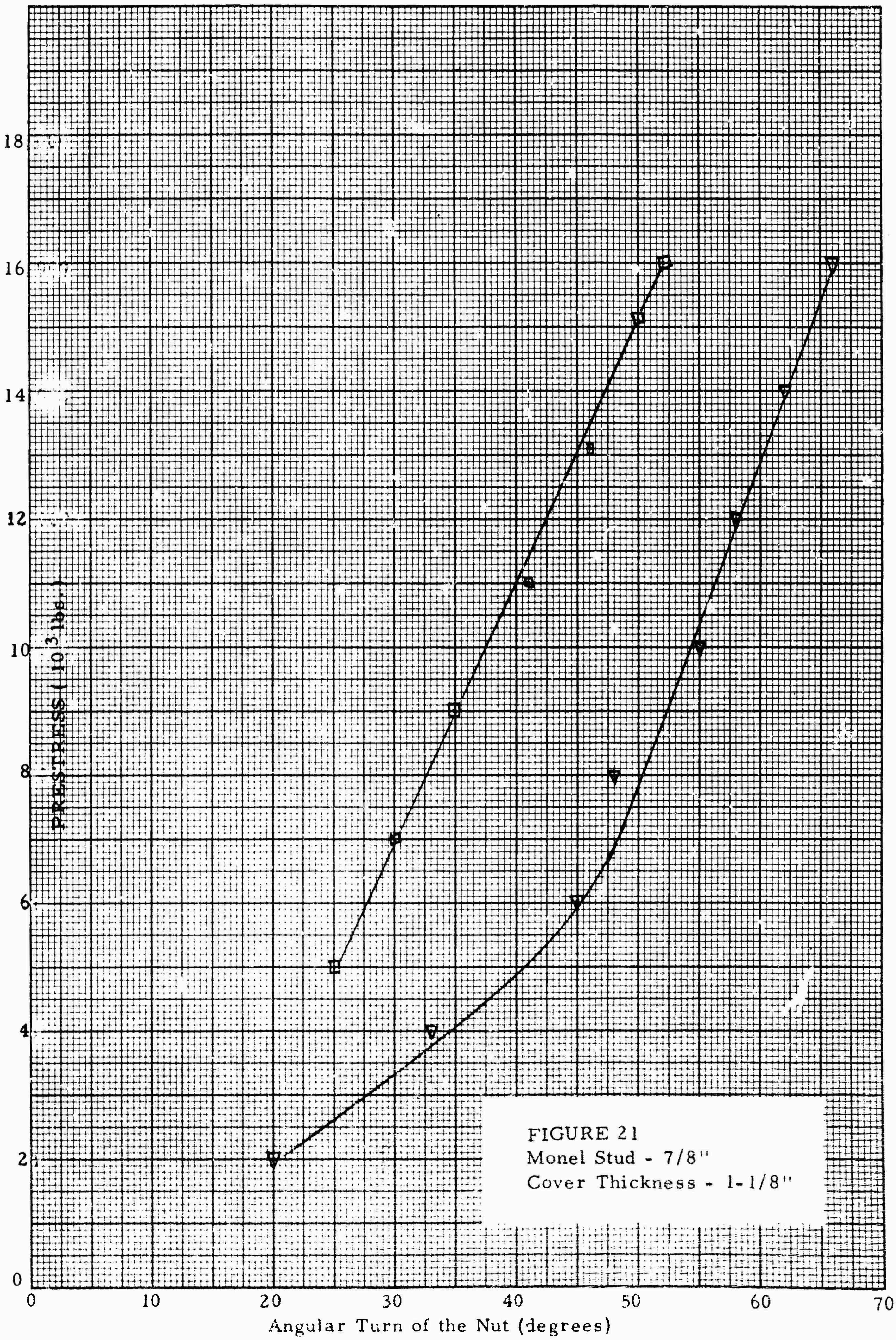


FIGURE 18
Monel Bolt
Shoulder Thickness: 2 inches
Cover Thickness: 1-1/8 inches


Clamped Material
HTS
HY80
Cast HY80
Monel
Valve Bronze
FIGURE: 19
K-Monel Bolt
Shoulder Thickness: 9/16 inch
Cover Thickness: 9/16 inch
A = 1D
PRESTRESS (lbs)
14,000
12,000
10,000
8000
6000
4000
2000
0
20
40
60
80
100
120
APPLIED TORQUE (ft-lb)



Clamped Material
HTS
HY80
Cast HY80
Monel
Valve Bronze
FIGURE: 20
K-Monel Bolt
Shoulder Thickness: 2 inches
Cover Thickness: 1-1/8 inches
PRESTRESS (lbs)
14,000
12,000
10,000
8000
6000
4000
2000
0
0
20
40
60
80
100
120
140
160
180
200
APPLIED TORQUE (ft-lb)


18
16
14
12
10
8
6
4
2
0
PRESTRESS (10^3 lbs.)
0
10
20
30
40
50
60
70
Angular Turn of the Nut (degrees)
FIGURE 21
Monel Stud - 7/8"
Cover Thickness - 1-1/8"

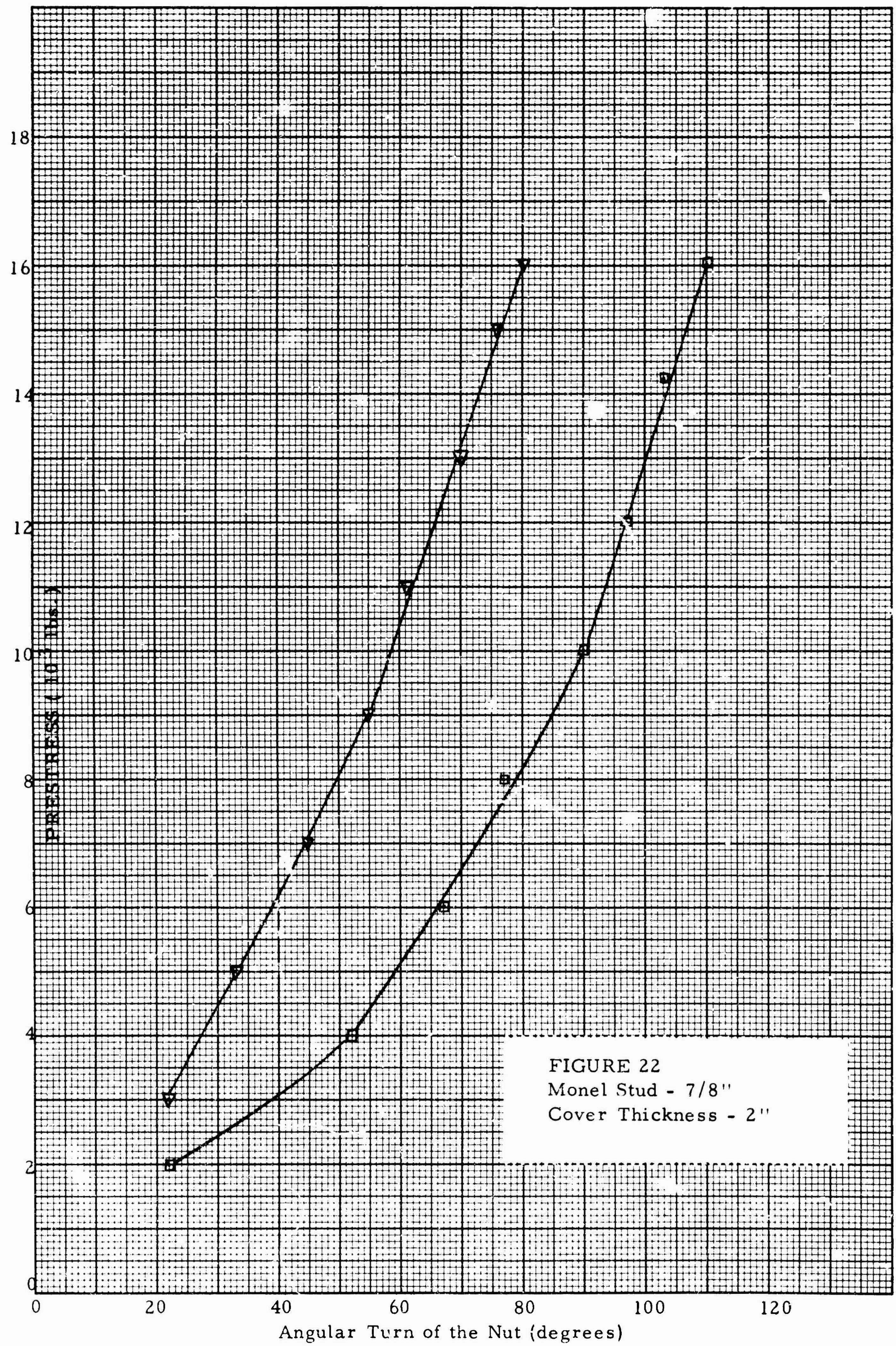


FIGURE 22
Monel Stud - 7/8"
Cover Thickness - 2"

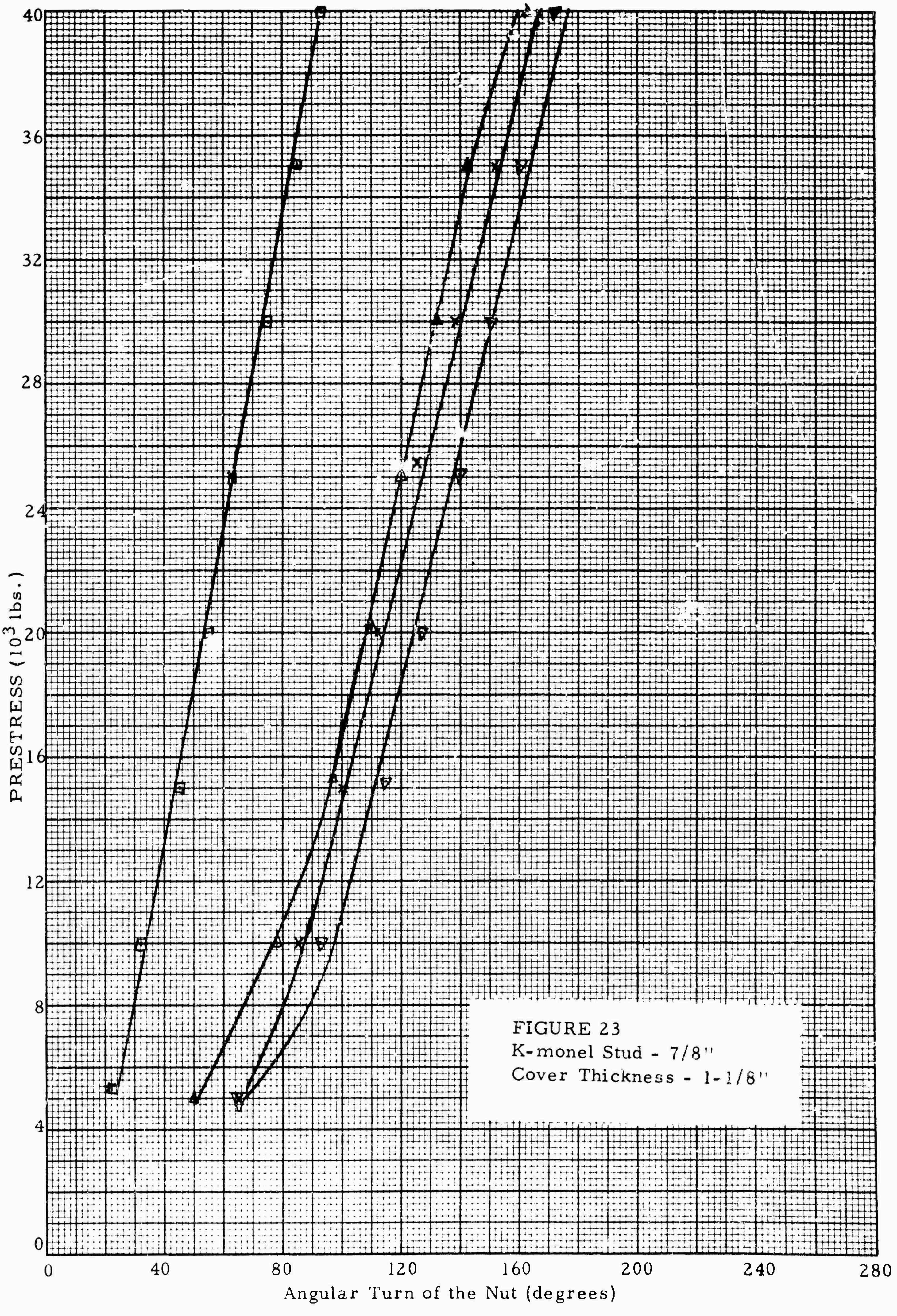


FIGURE 23
K-monel Stud - 7/8"
Cover Thickness - 1-1/8"
PRESTRESS (10^3 lbs.)
Angular Turn of the Nut (degrees)
0
4
8
12
16
20
24
28
32
36
40
0
40
80
120
160
200
240
280

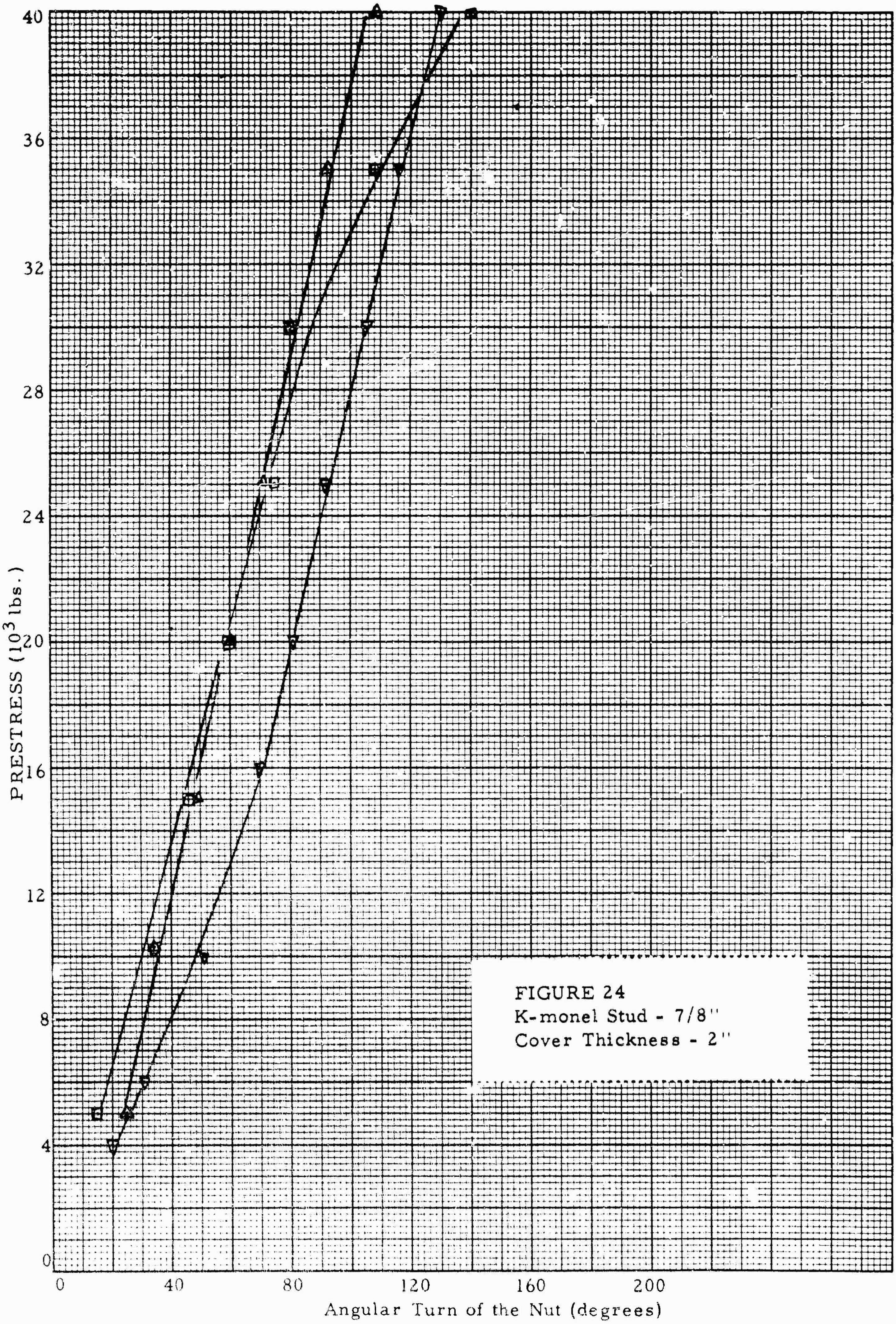


FIGURE 24
K-monel Stud - 7/8"
Cover Thickness - 2"

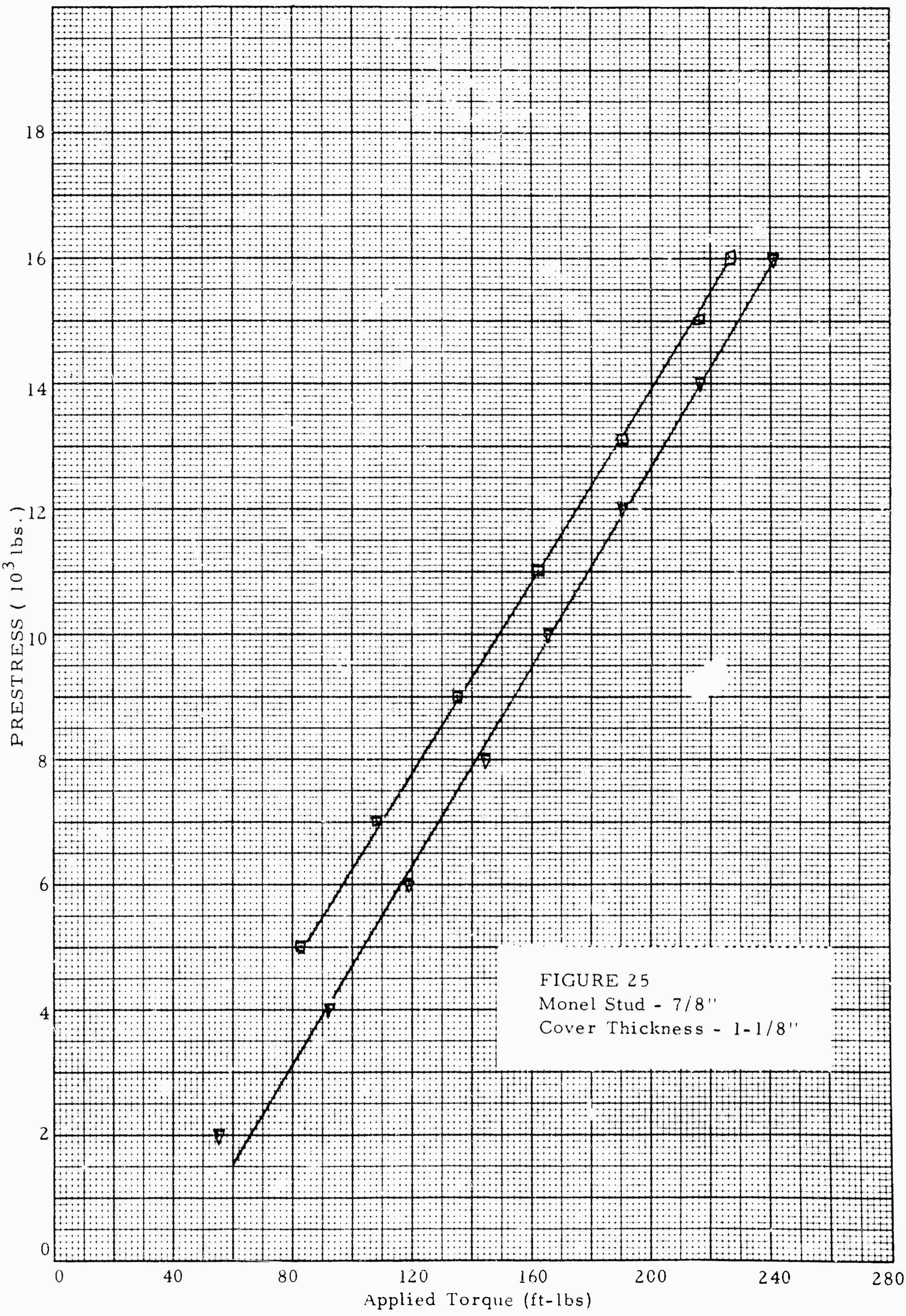


FIGURE 25
Monel Stud - 7/8"
Cover Thickness - 1-1/8"

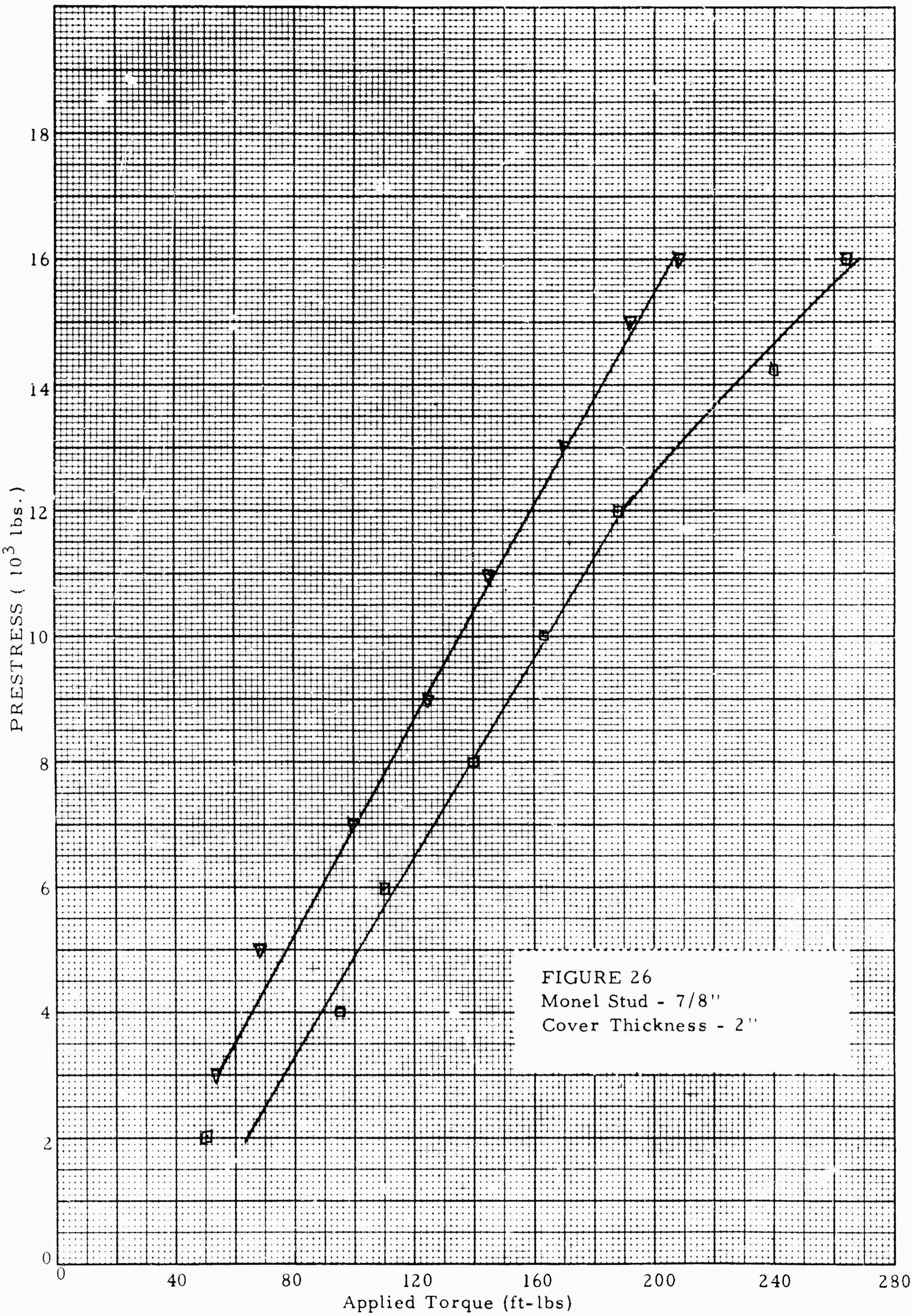


FIGURE 26
Monel Stud - 7/8"
Cover Thickness - 2"
PRESTRESS (10^3 lbs.)
Applied Torque (ft-lbs)
0
2
4
6
8
10
12
14
16
18
0
40
80
120
160
200
240
280

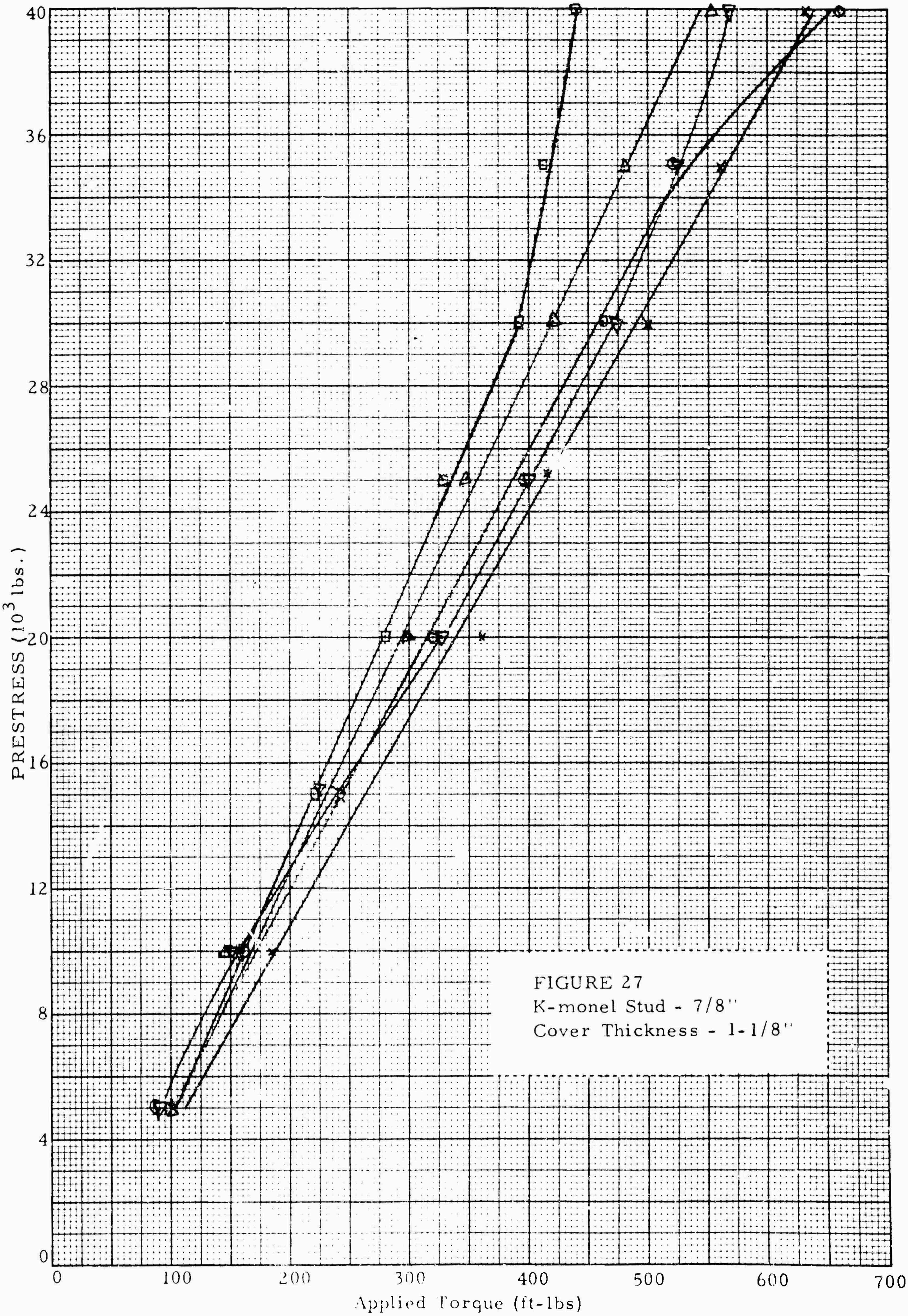


FIGURE 27
K-monel Stud - 7/8"
Cover Thickness - 1-1/8"

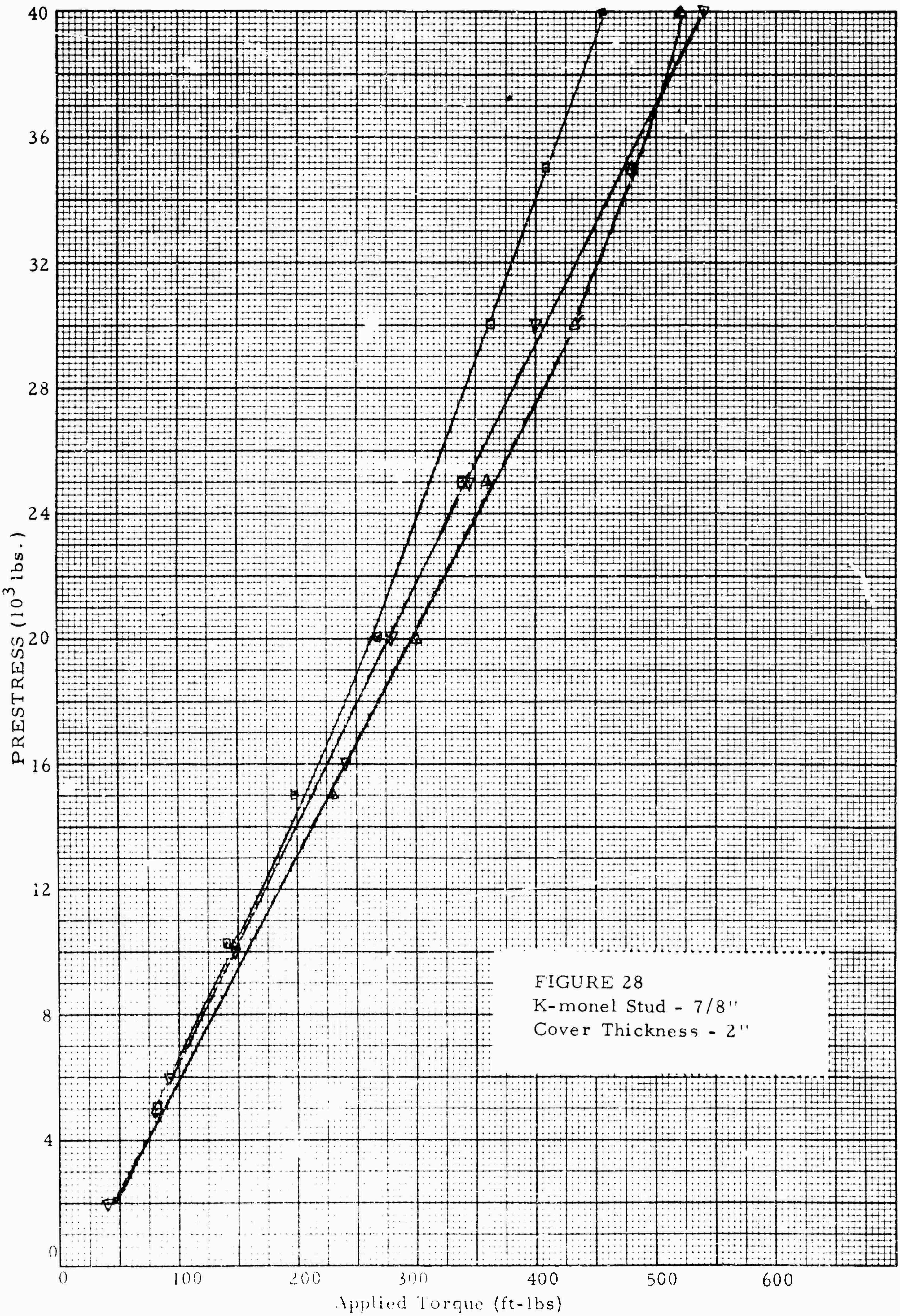
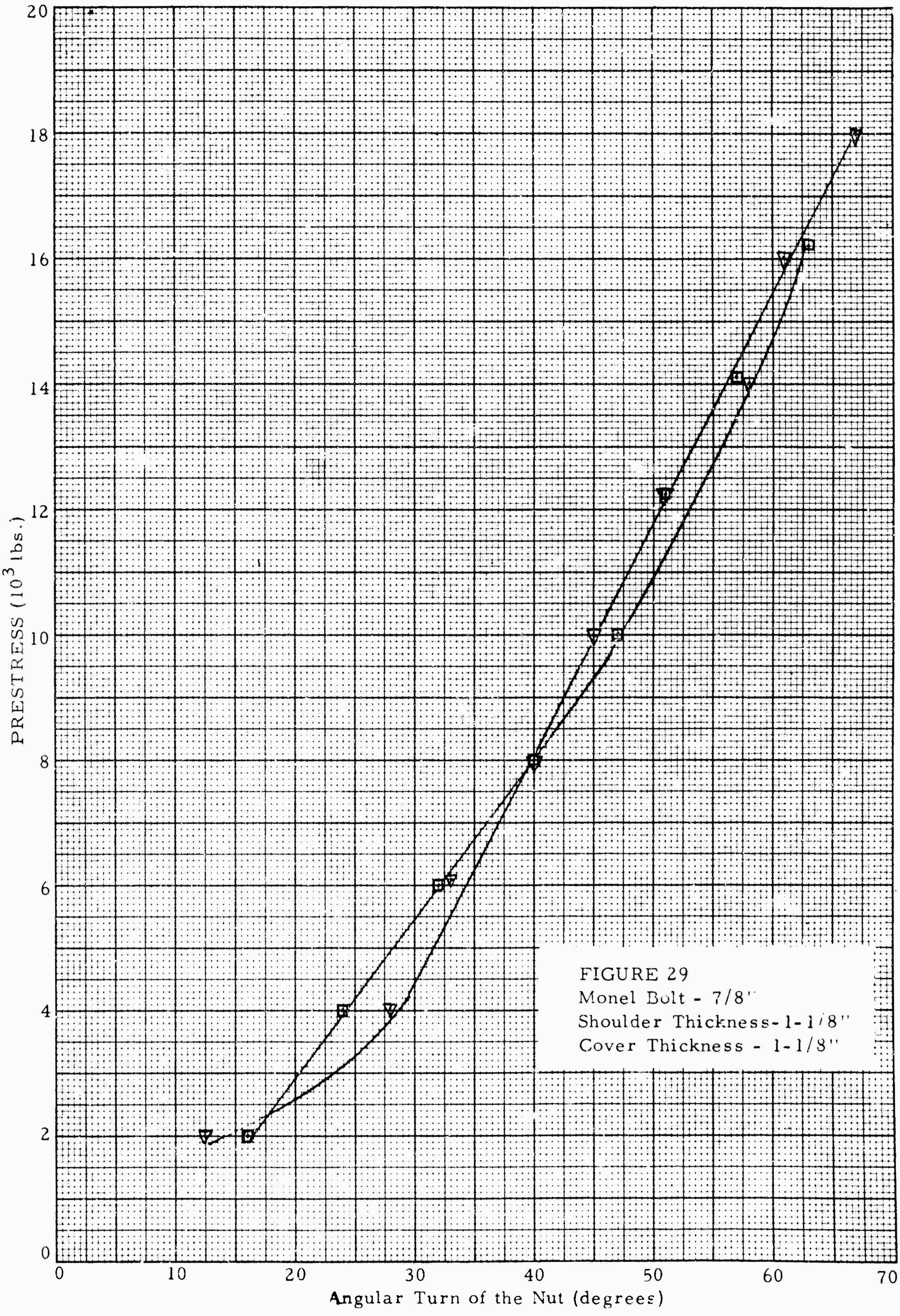
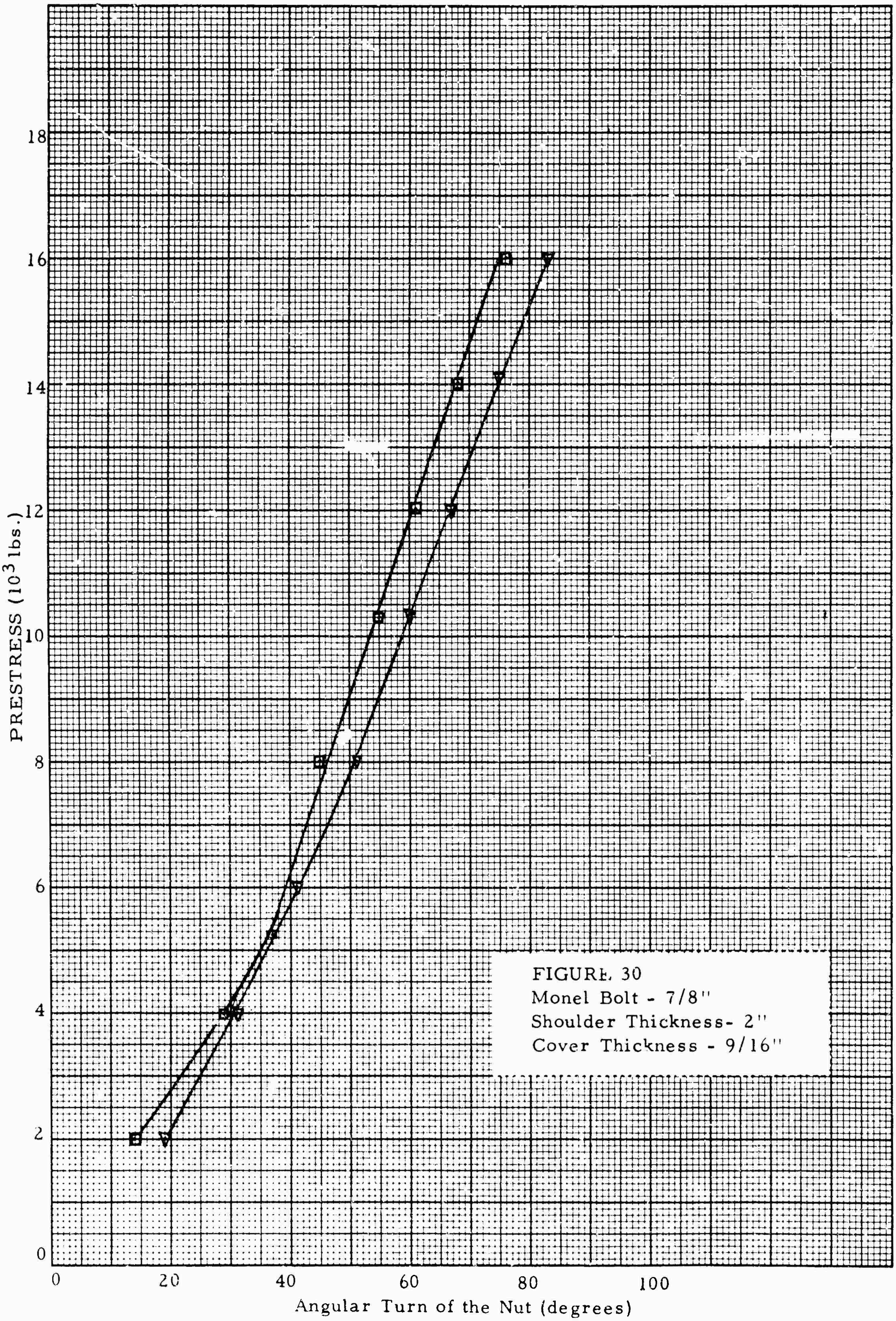


FIGURE 28
K-monel Stud - 7/8"
Cover Thickness - 2"


PRESTRESS (10^3 lbs.)
Angular Turn of the Nut (degrees)
0
2
4
6
8
10
12
14
16
18
20
0
10
20
30
40
50
60
70
FIGURE 29
Monel Bolt - 7/8"
Shoulder Thickness - 1-1/8"
Cover Thickness - 1-1/8"


PRESTRESS (10^3 lbs.)
0
2
4
6
8
10
12
14
16
18
0
20
40
60
80
100
Angular Turn of the Nut (degrees)
FIGURE 30
Monel Bolt - 7/8"
Shoulder Thickness- 2"
Cover Thickness - 9/16"

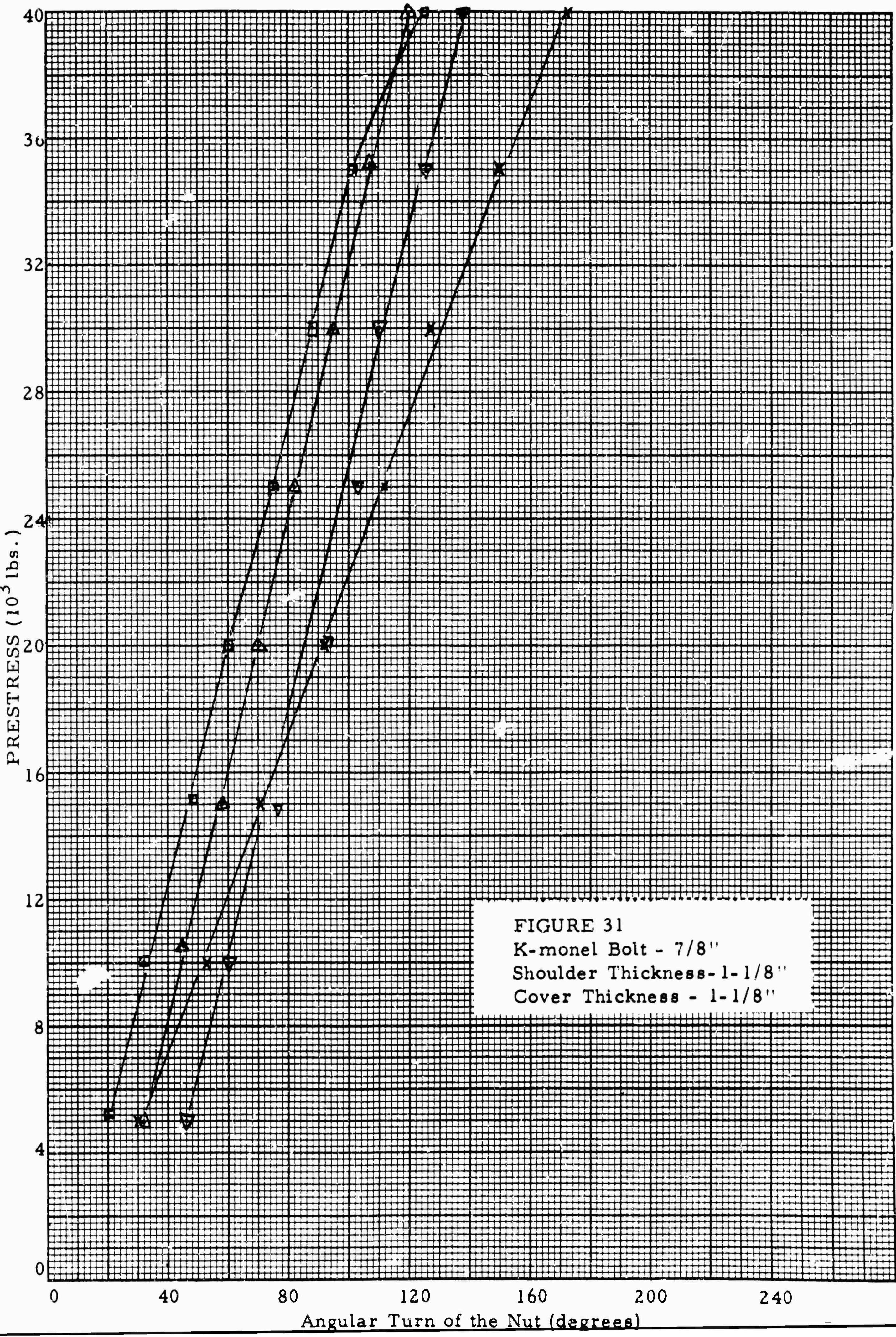
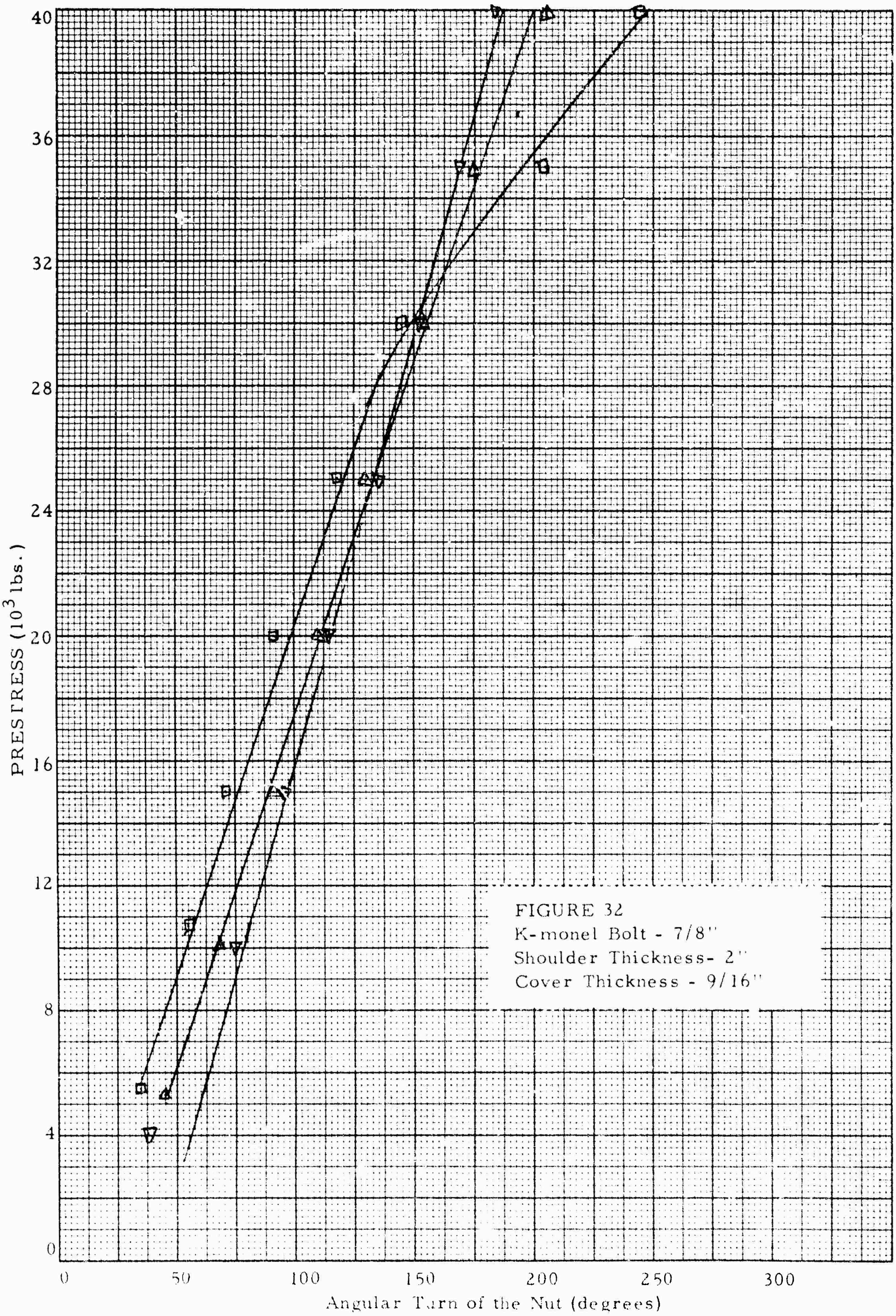
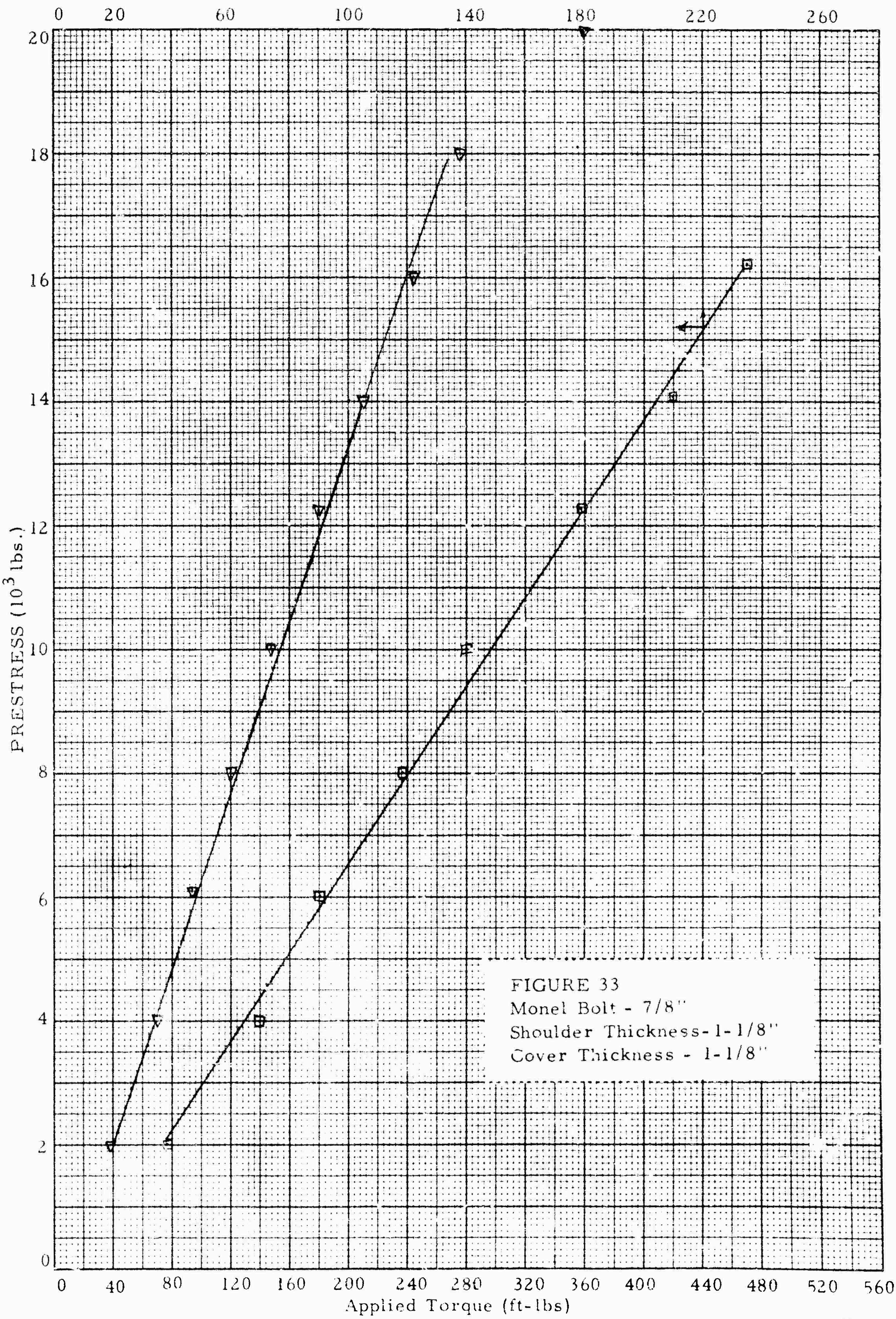


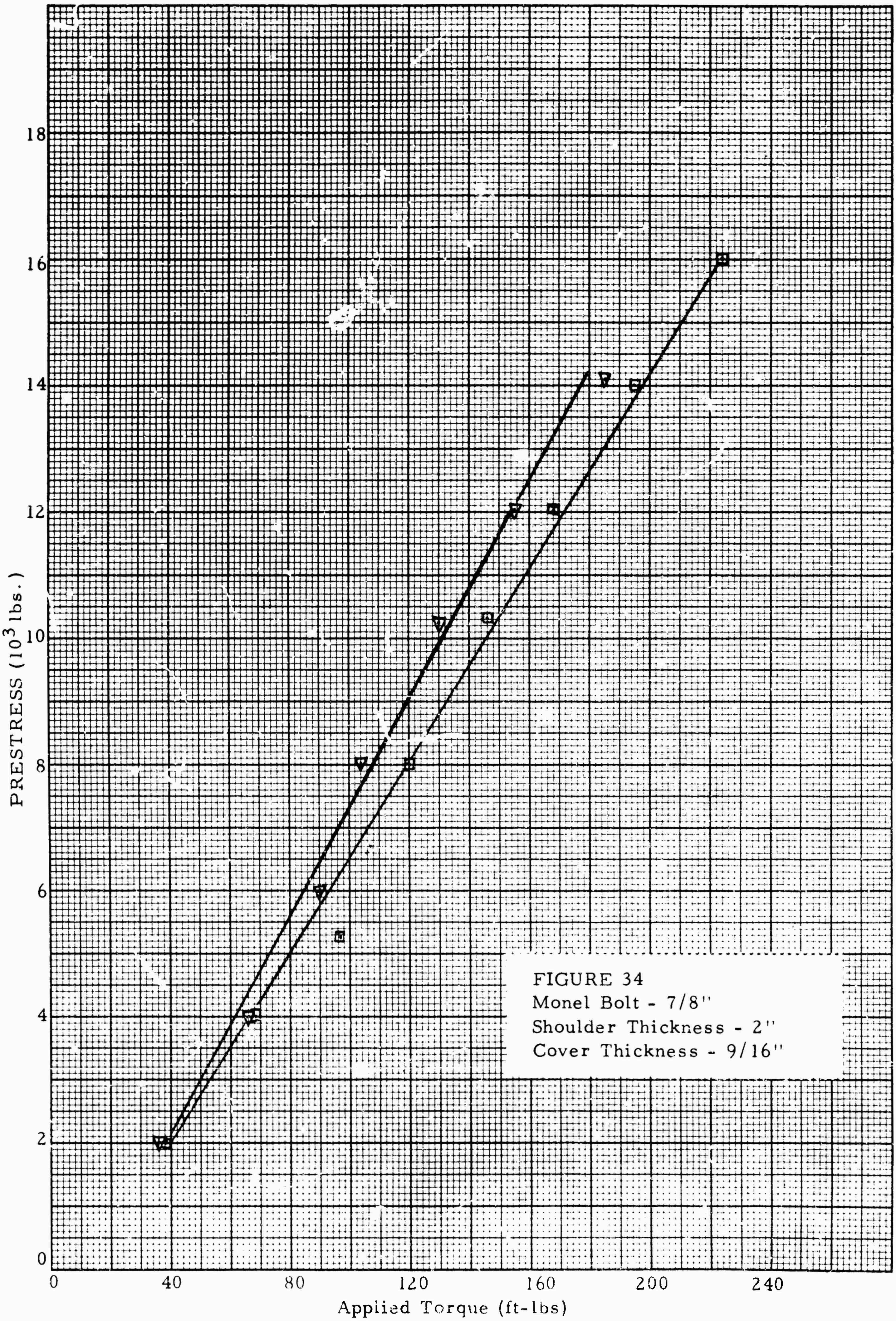
FIGURE 31
K-monel Bolt - 7/8"
Shoulder Thickness - 1-1/8"
Cover Thickness - 1-1/8"
PRESTRESS (10^3 lbs.)
Angular Turn of the Nut (degrees)
0
4
8
12
16
20
24
28
32
36
40
0
40
80
120
160
200
240



40
36
32
28
24
20
16
12
8
4
0
PRESTRESS (10^3 lbs.)
0
50
100
150
200
250
300
Angular Turn of the Nut (degrees)
FIGURE 32
K-monel Bolt - 7/8"
Shoulder Thickness- 2"
Cover Thickness - 9/16"



0 20 60 100 140 180 220 260
PRESTRESS (10^3 lbs.)
0 2 4 6 8 10 12 14 16 18 20
0 40 80 120 160 200 240 280 320 360 400 440 480 520 560
Applied Torque (ft-lbs)
FIGURE 33
Monel Bolt - 7/8"
Shoulder Thickness-1-1/8"
Cover Thickness - 1-1/8"



PRESTRESS (10^3 lbs.)
Applied Torque (ft-lbs)
0
2
4
6
8
10
12
14
16
18
0
40
80
120
160
200
240
FIGURE 34
Monel Bolt - 7/8"
Shoulder Thickness - 2"
Cover Thickness - 9/16"

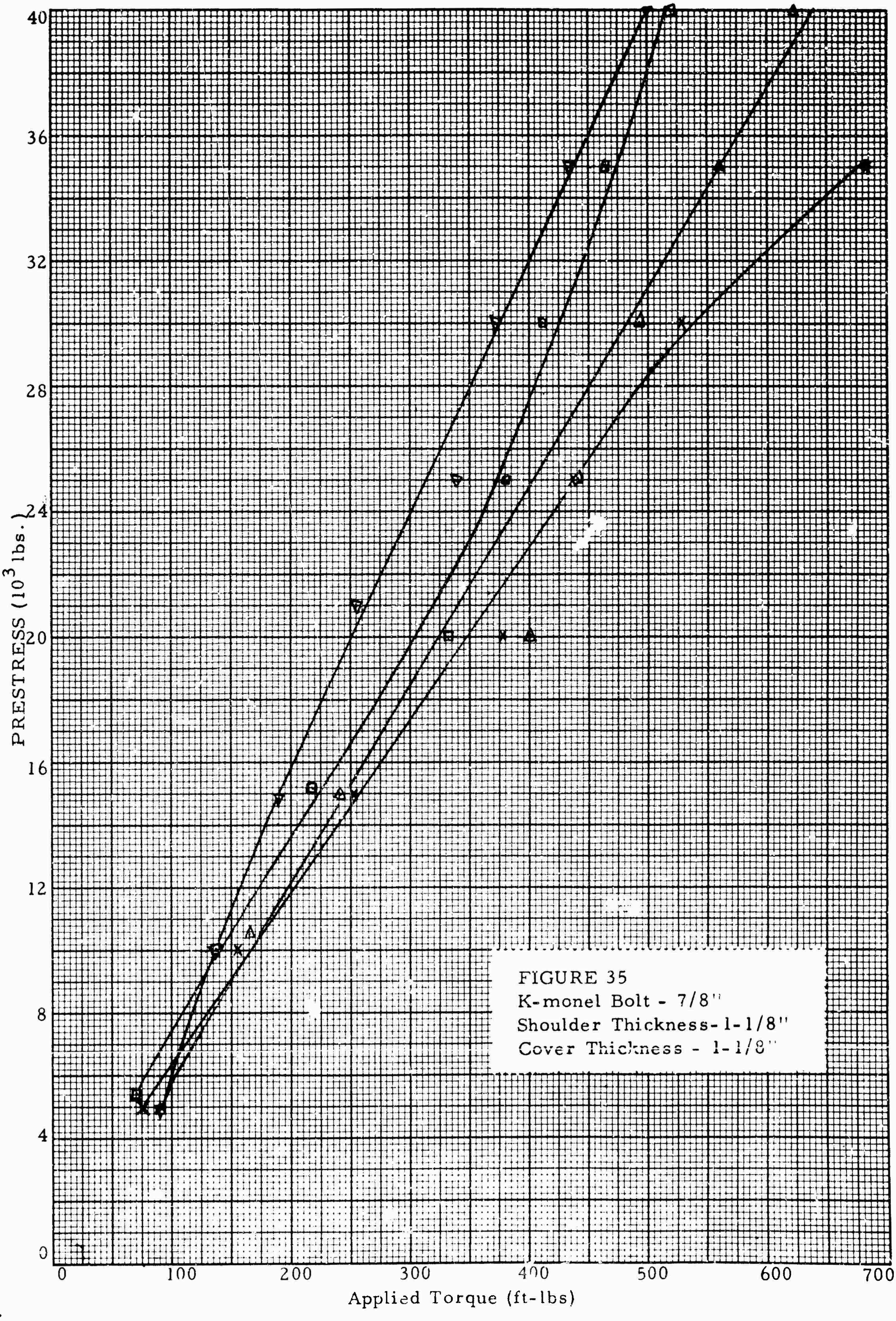
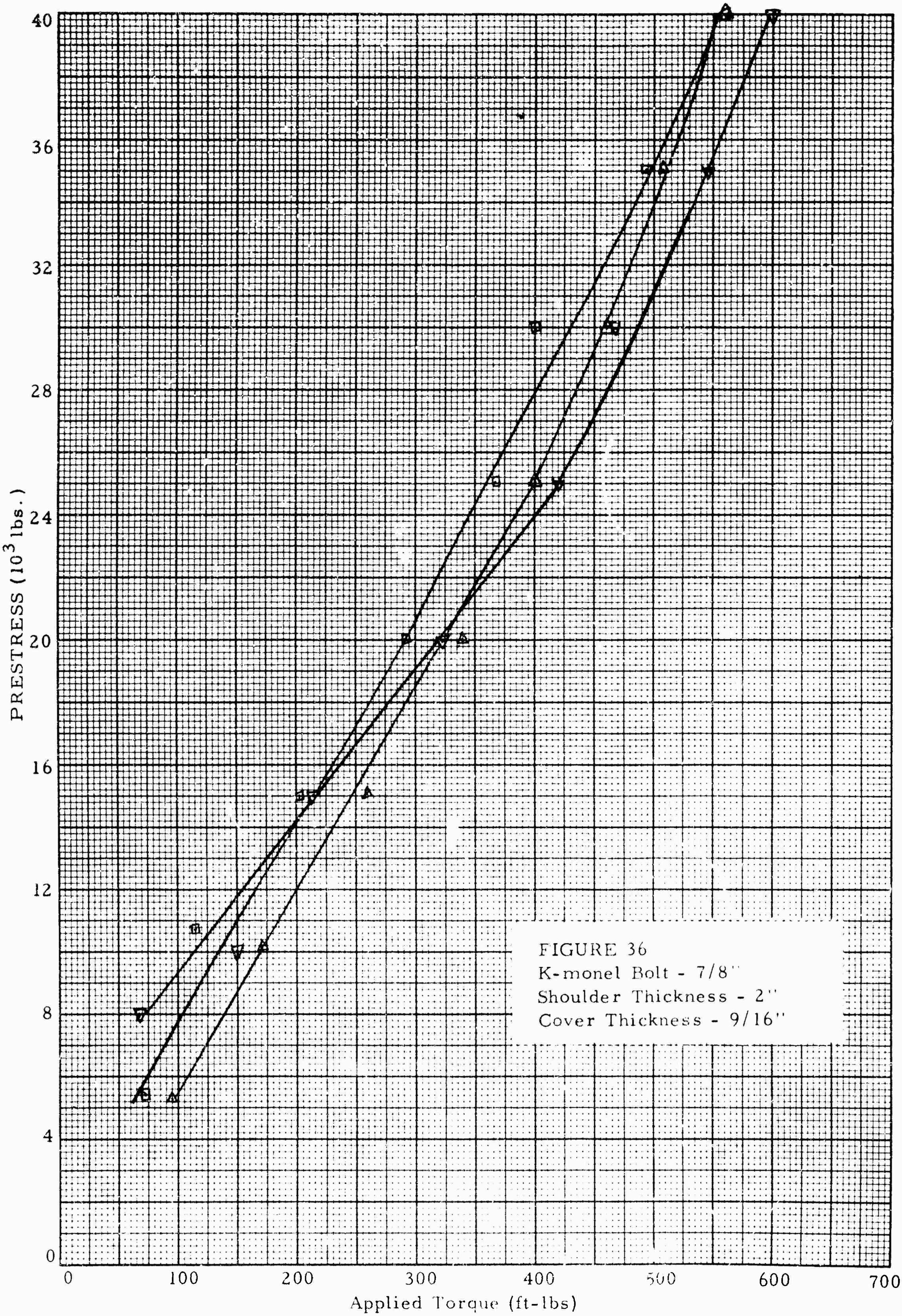


FIGURE 35
K-monel Bolt - 7/8"
Shoulder Thickness - 1-1/8"
Cover Thickness - 1-1/8"


PRESTRESS (10^3 lbs.)
0
4
8
12
16
20
24
28
32
36
40
0
100
200
300
400
500
600
700
Applied Torque (ft-lbs)
FIGURE 36
K-monel Bolt - 7/8"
Shoulder Thickness - 2"
Cover Thickness - 9/16"

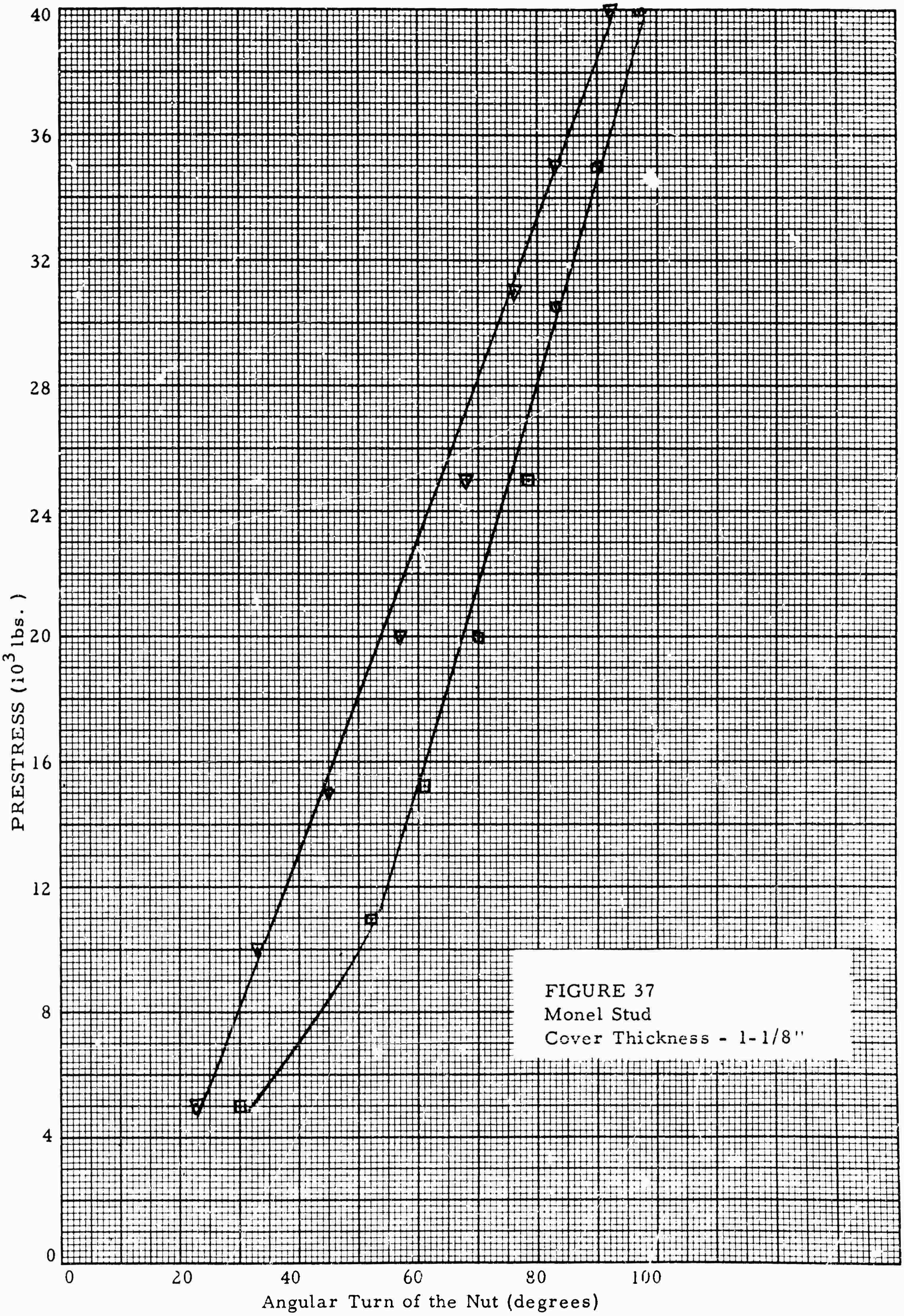


FIGURE 37
Monel Stud
Cover Thickness - 1-1/8"

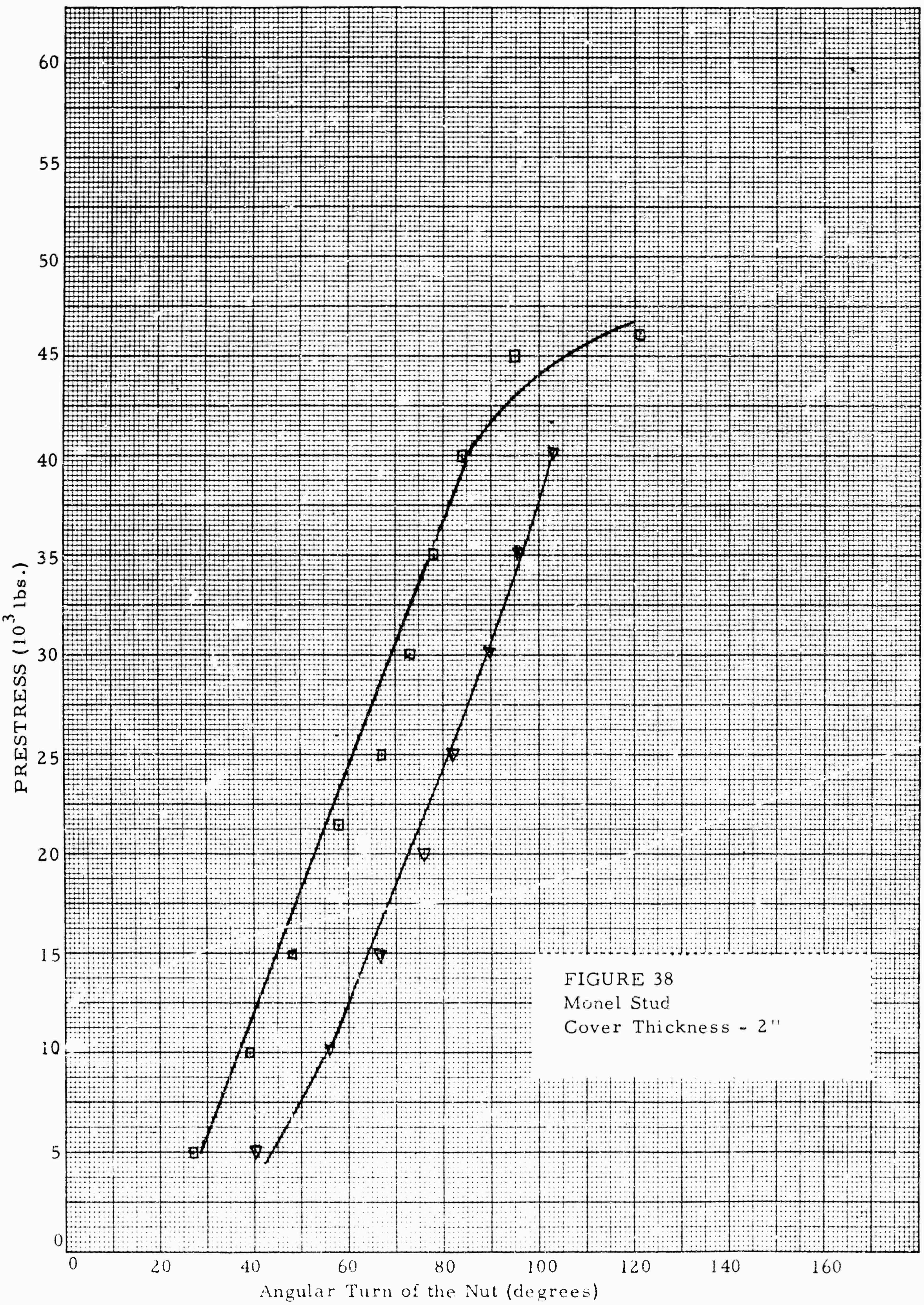


FIGURE 38
Monel Stud
Cover Thickness - 2"

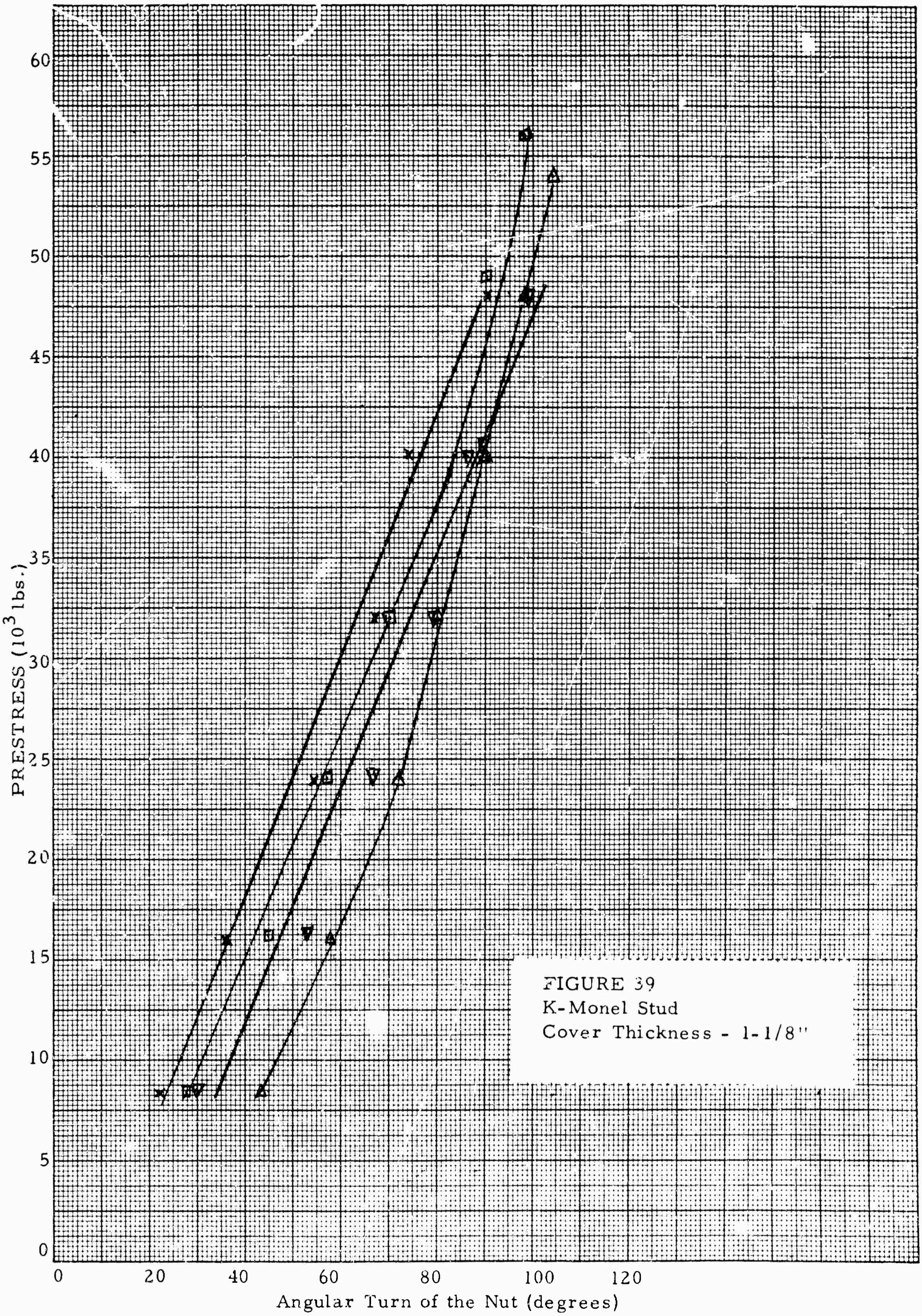
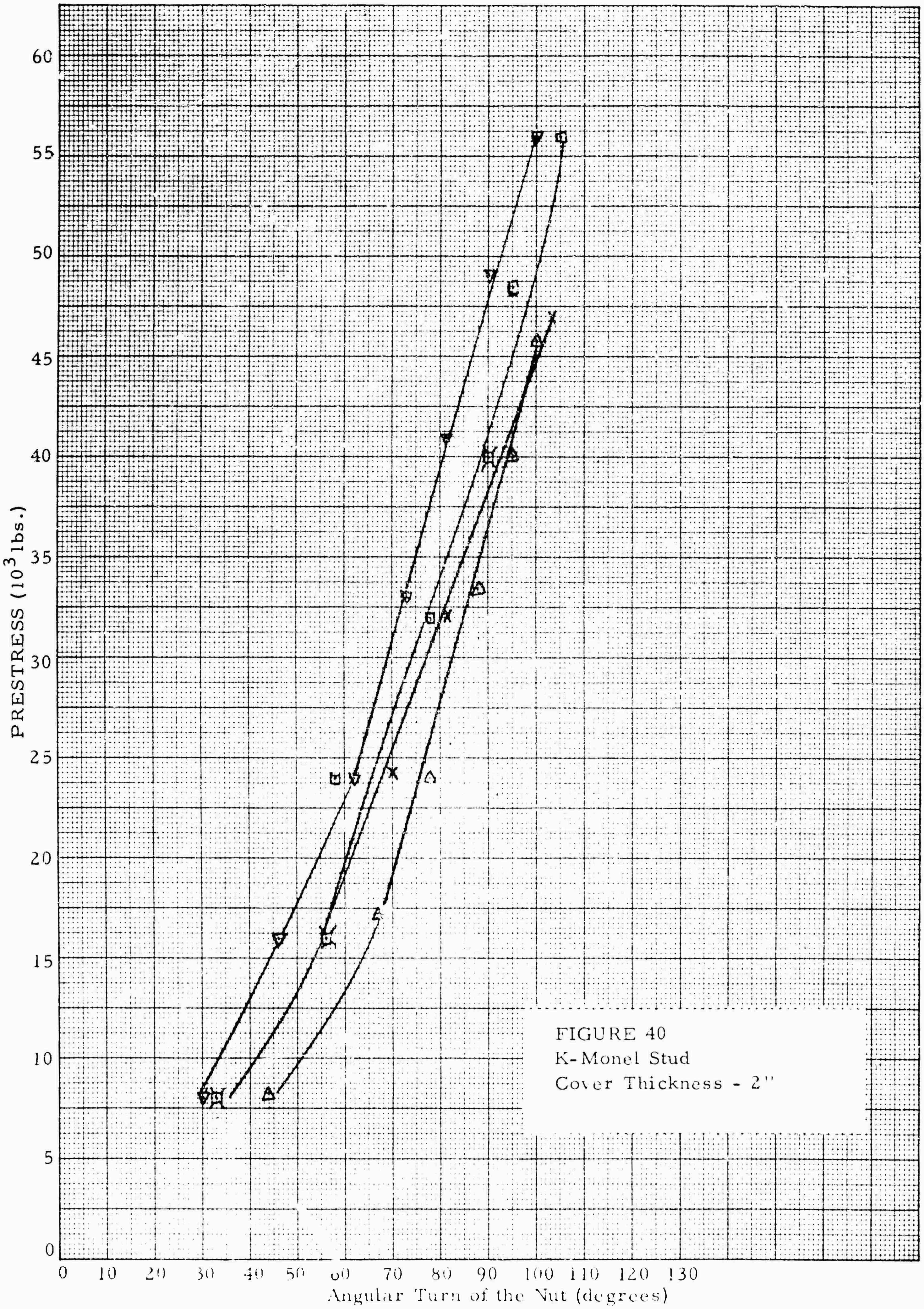


FIGURE 39
K-Monel Stud
Cover Thickness - 1-1/8"


PRESTRESS (10^3 lbs.)
0
5
10
15
20
25
30
35
40
45
50
55
60
0 10 20 30 40 50 60 70 80 90 100 110 120 130
Angular Turn of the Nut (degrees)
FIGURE 40
K-Monel Stud
Cover Thickness - 2"

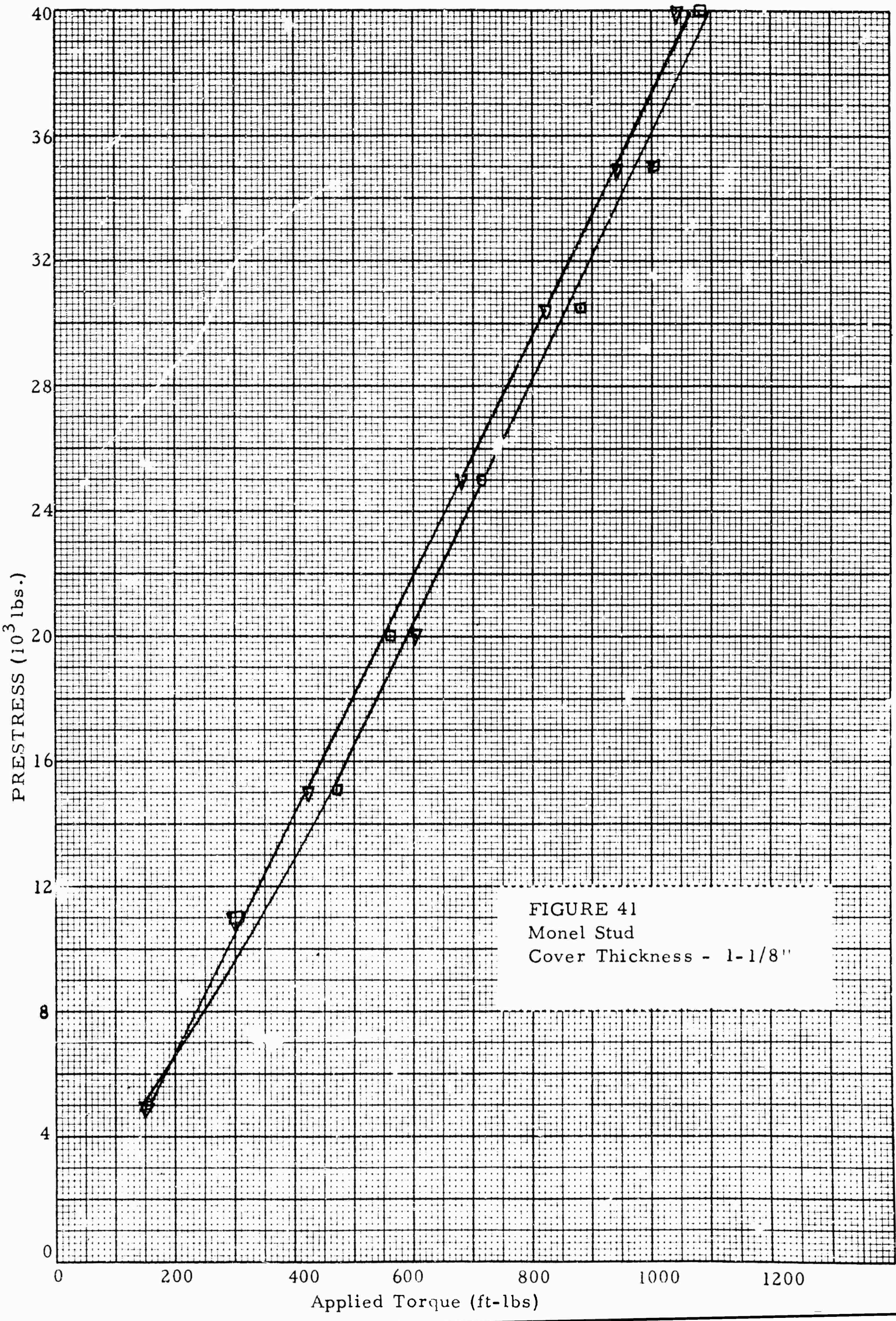


FIGURE 41
Monel Stud
Cover Thickness - 1-1/8"
PRESTRESS (10^3 lbs.)
Applied Torque (ft-lbs)
0
4
8
12
16
20
24
28
32
36
40
0
200
400
600
800
1000
1200

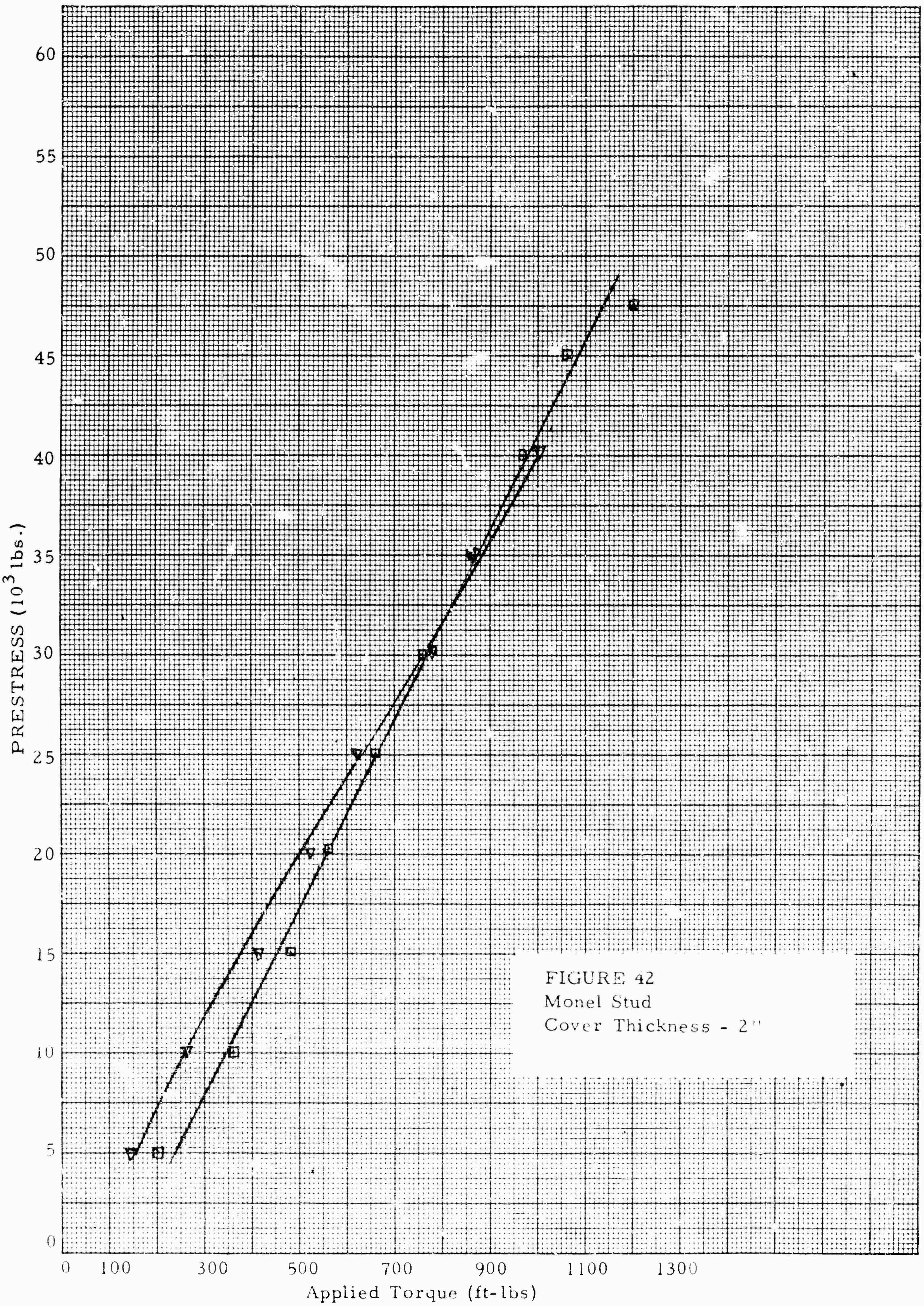


FIGURE 42
Monel Stud
Cover Thickness - 2"

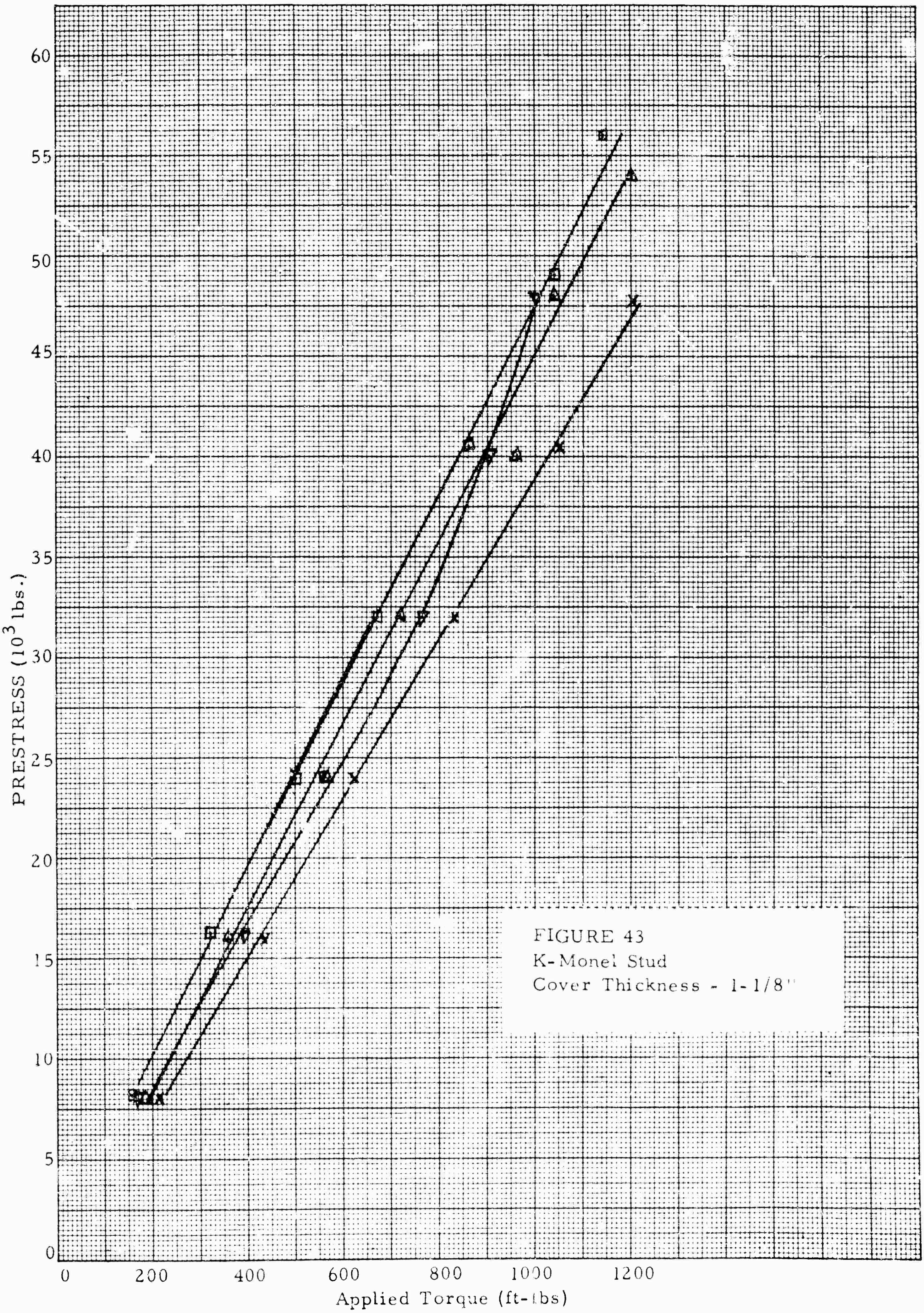
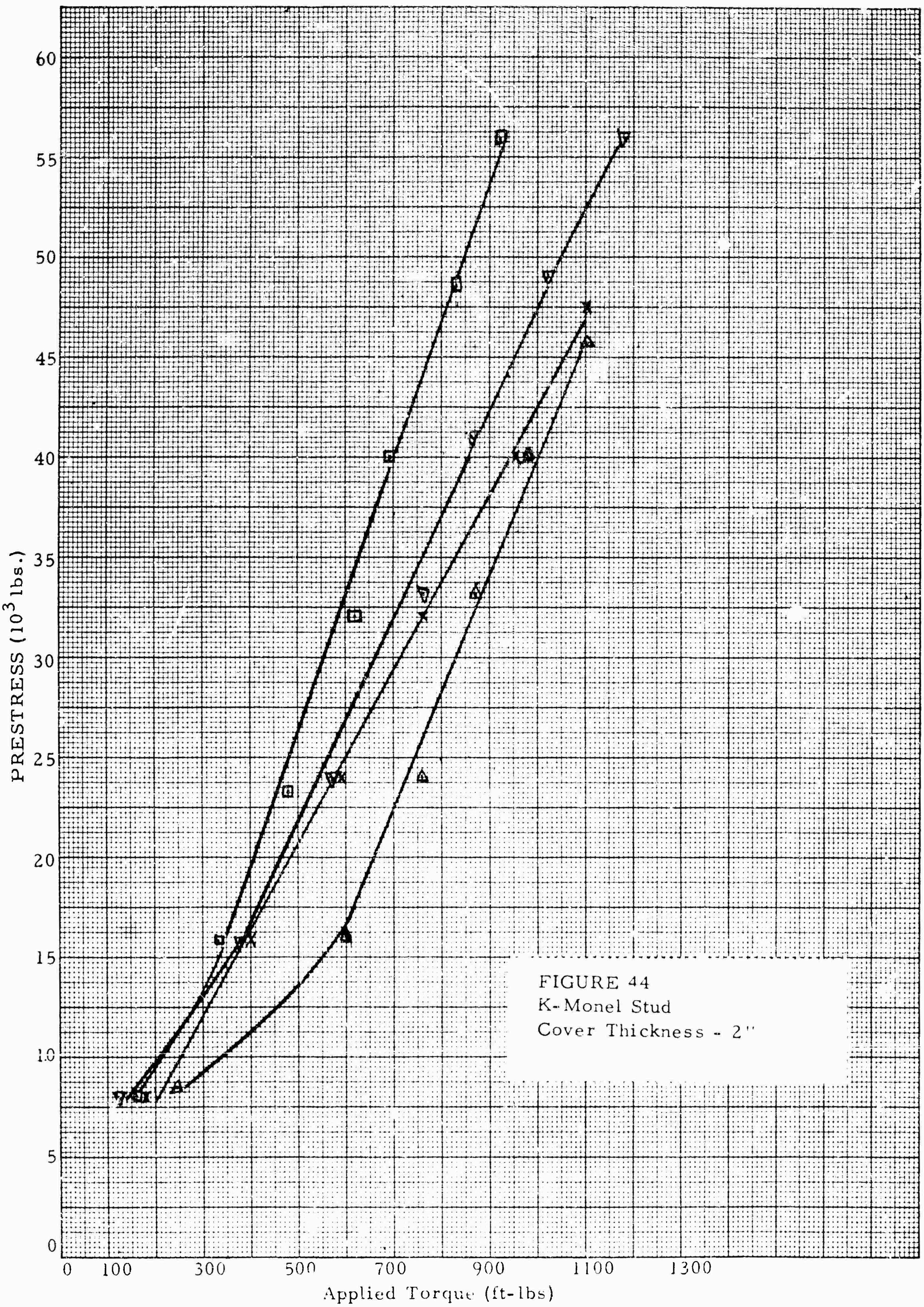


FIGURE 43
K-Monel Stud
Cover Thickness - 1-1/8"


PRESTRESS (10^3 lbs.)
0
5
10
15
20
25
30
35
40
45
50
55
60
0
100
300
500
700
900
1100
1300
Applied Torque (ft-lbs)
FIGURE 44
K-Monel Stud
Cover Thickness - 2"

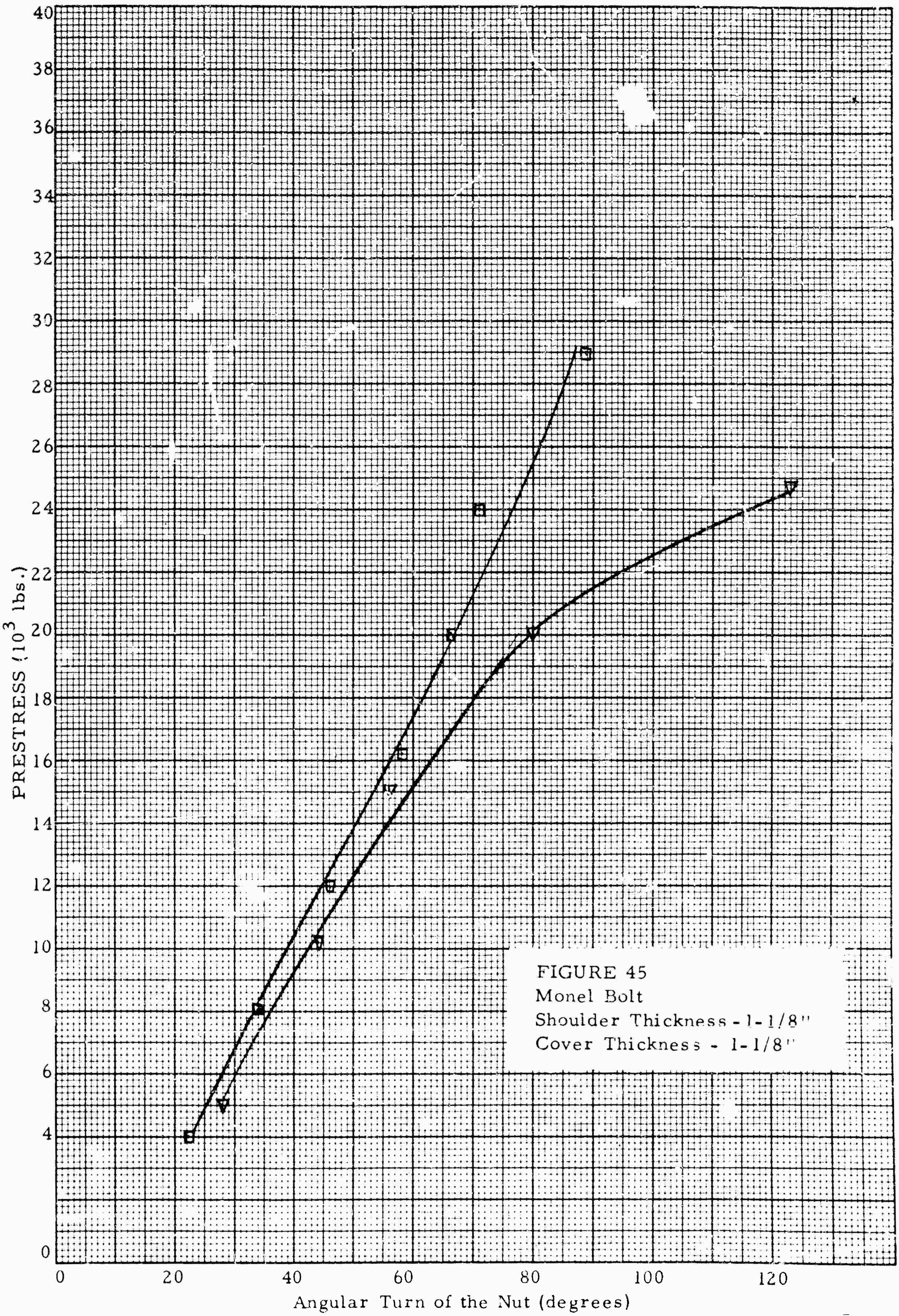


FIGURE 45
Monel Bolt
Shoulder Thickness - 1-1/8"
Cover Thickness - 1-1/8"

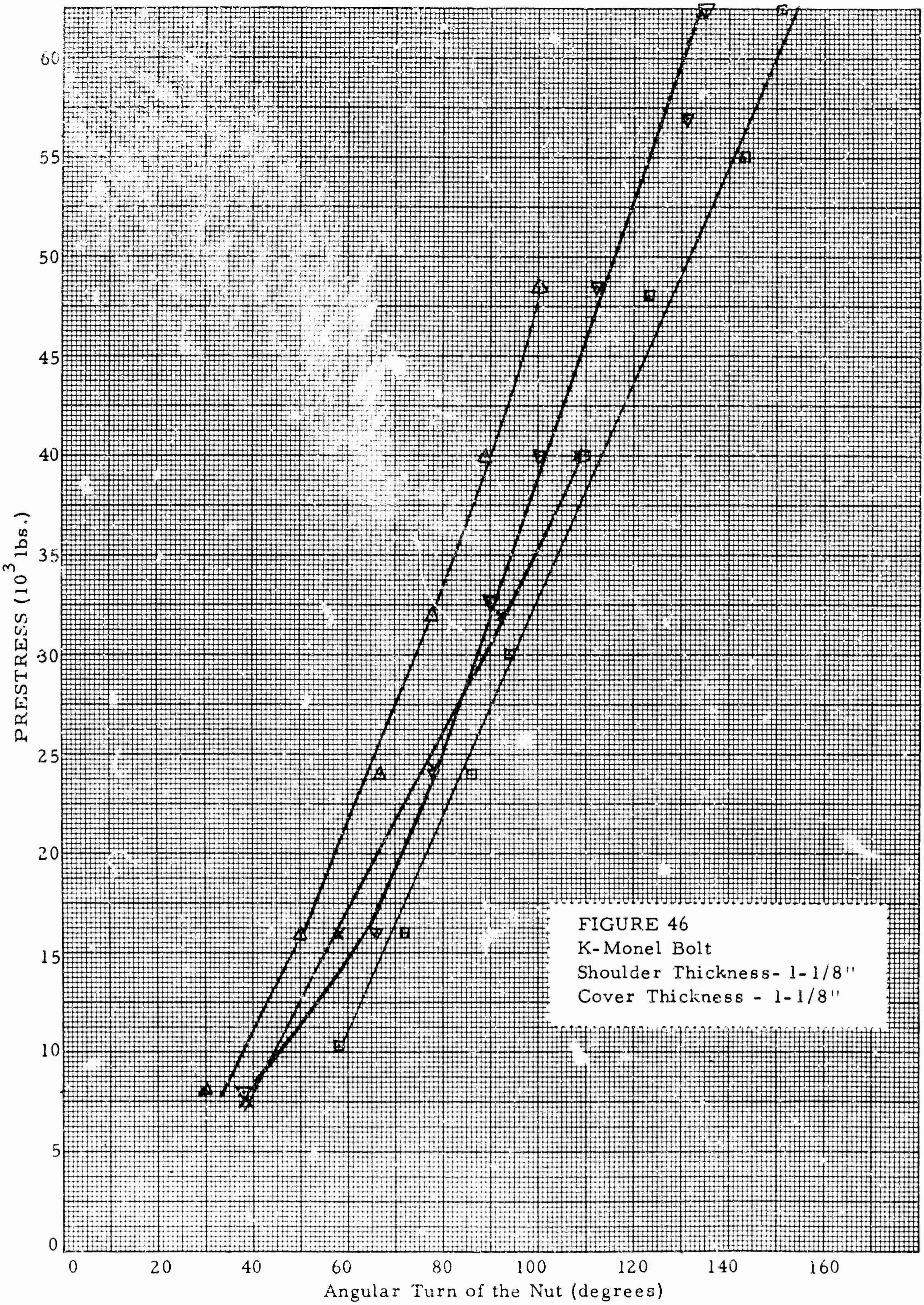
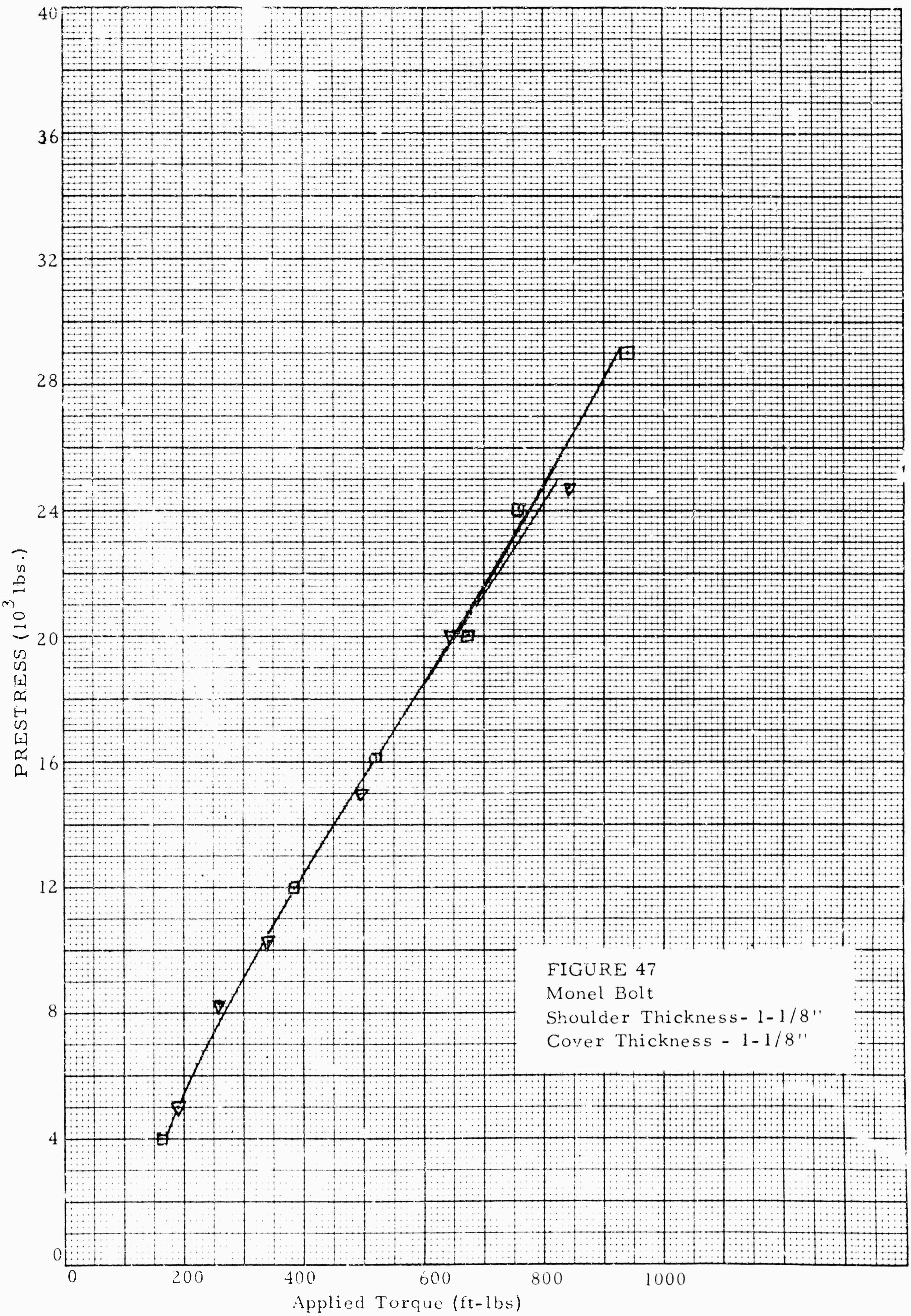


FIGURE 46
K-Monel Bolt
Shoulder Thickness- 1-1/8"
Cover Thickness - 1-1/8"



PRESTRESS (10^3 lbs.)
Applied Torque (ft-lbs)
FIGURE 47
Monel Bolt
Shoulder Thickness- 1-1/8"
Cover Thickness - 1-1/8"

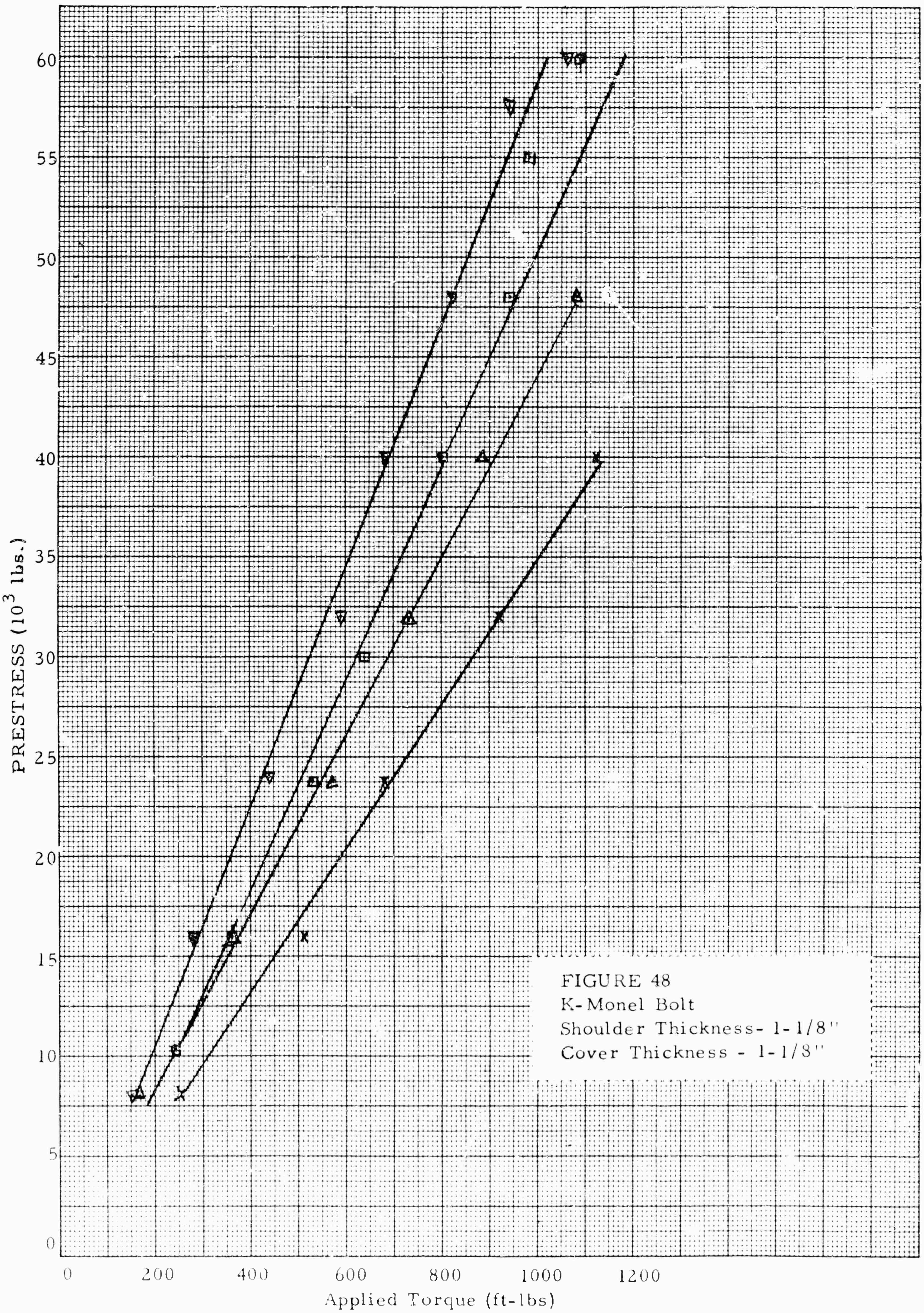


FIGURE 48
K-Monel Bolt
Shoulder Thickness- 1-1/8"
Cover Thickness - 1-1/8"

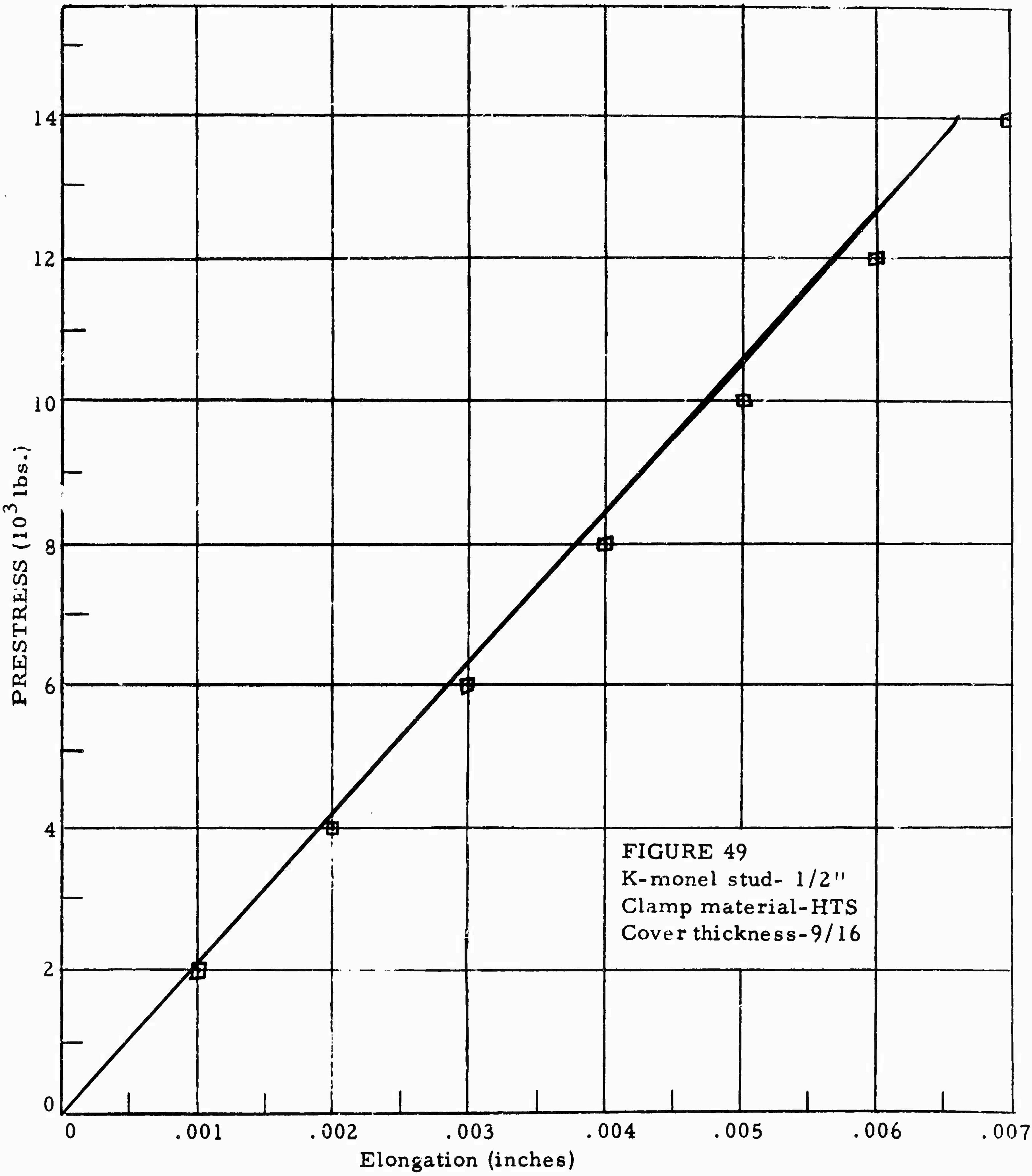


FIGURE 49
K-monel stud- 1/2"
Clamp material-HTS
Cover thickness-9/16

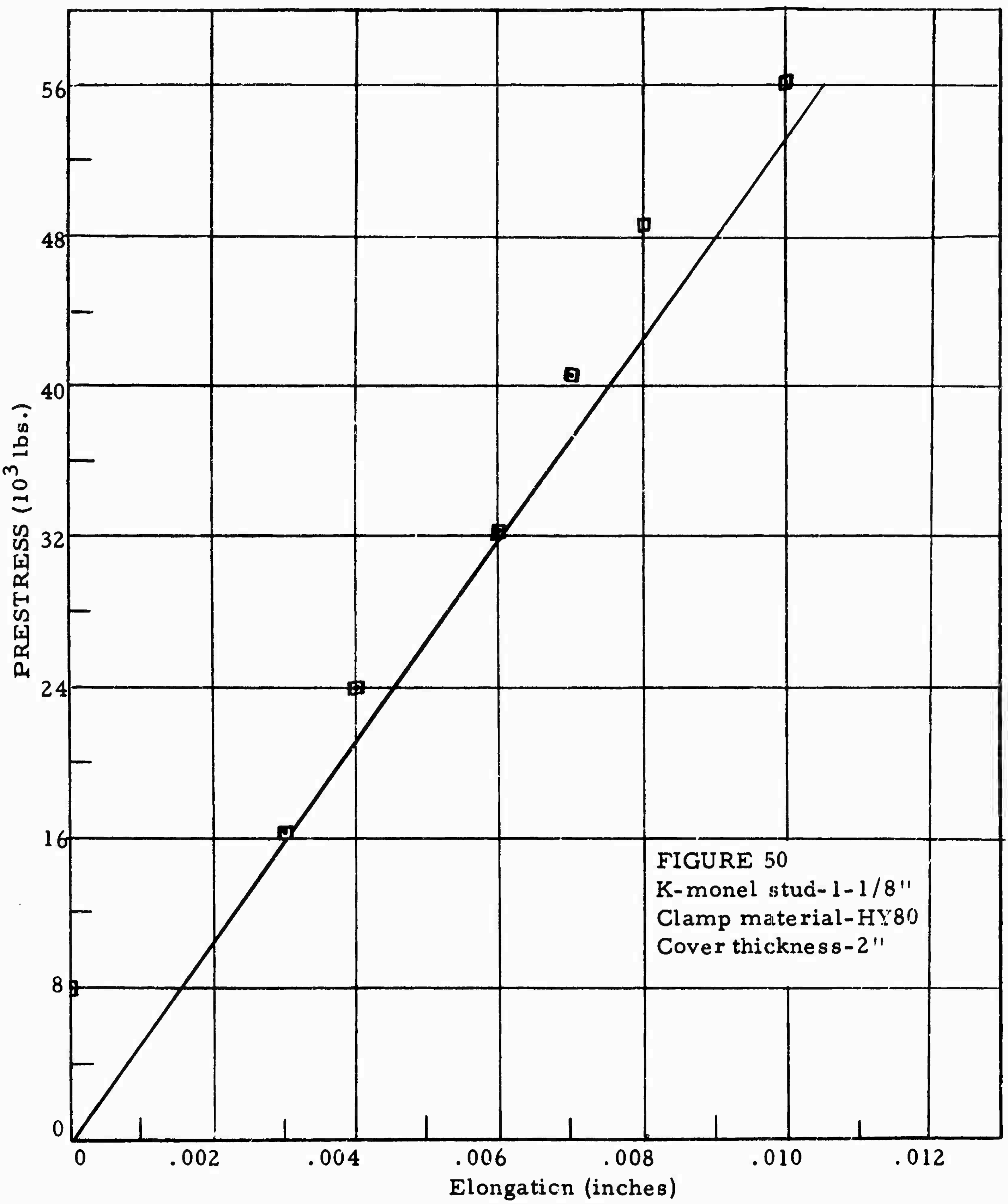


FIGURE 50
K-monel stud-1-1/8"
Clamp material-HY80
Cover thickness-2"

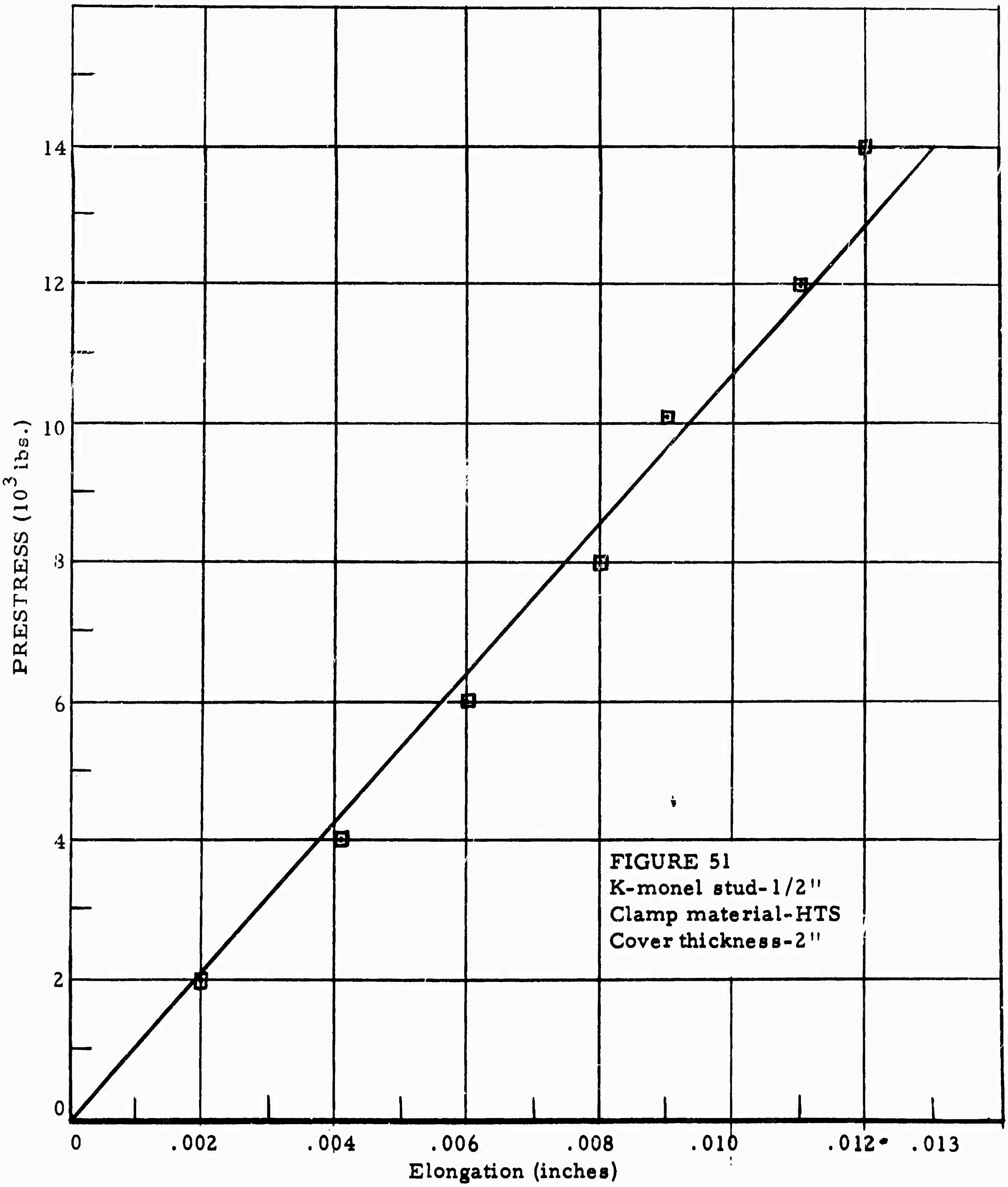


FIGURE 51
K-monel stud-1/2"
Clamp material-HTS
Cover thickness-2"

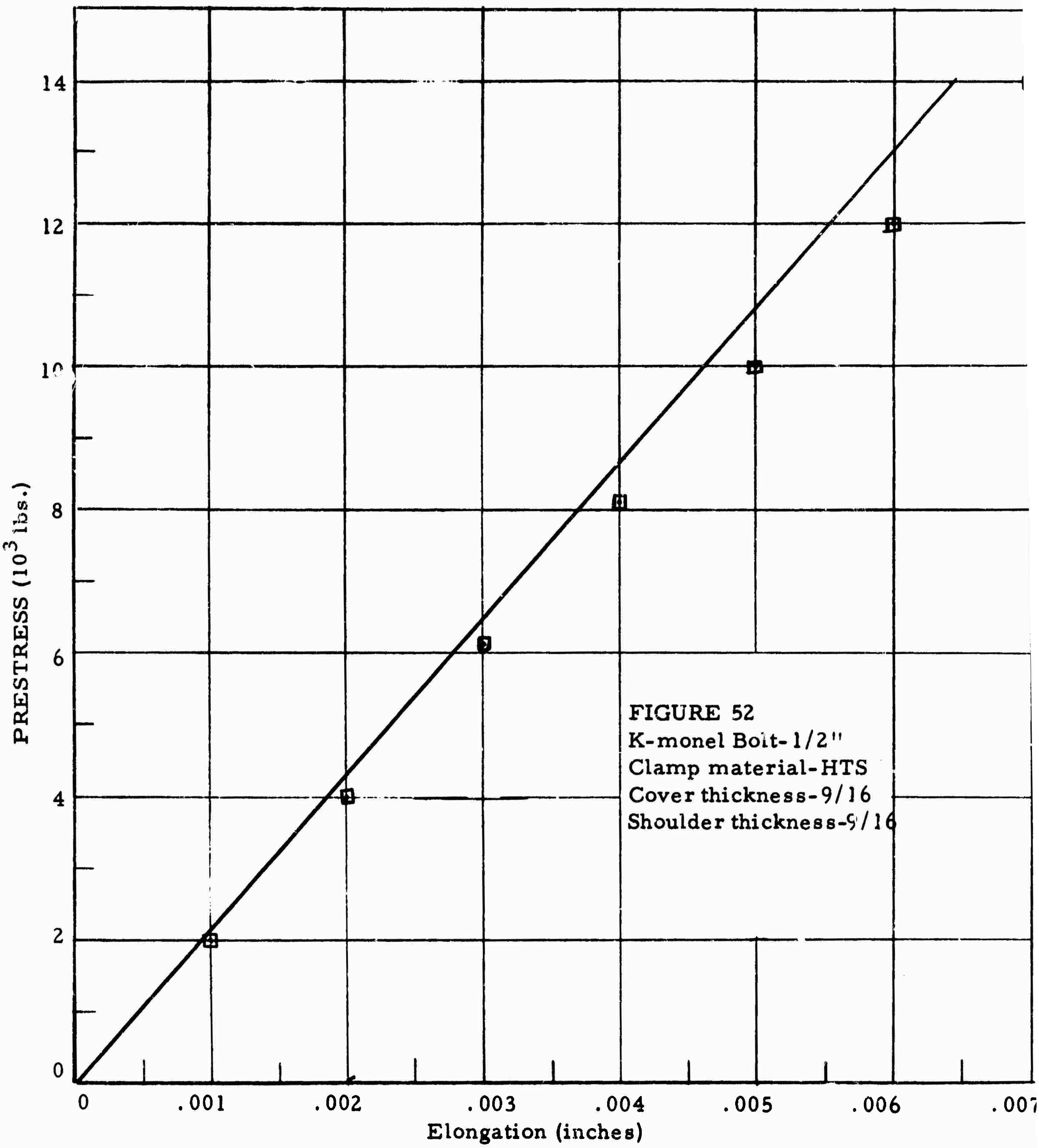


FIGURE 52
K-monel Bolt-1/2"
Clamp material-HTS
Cover thickness-9/16
Shoulder thickness-9/16

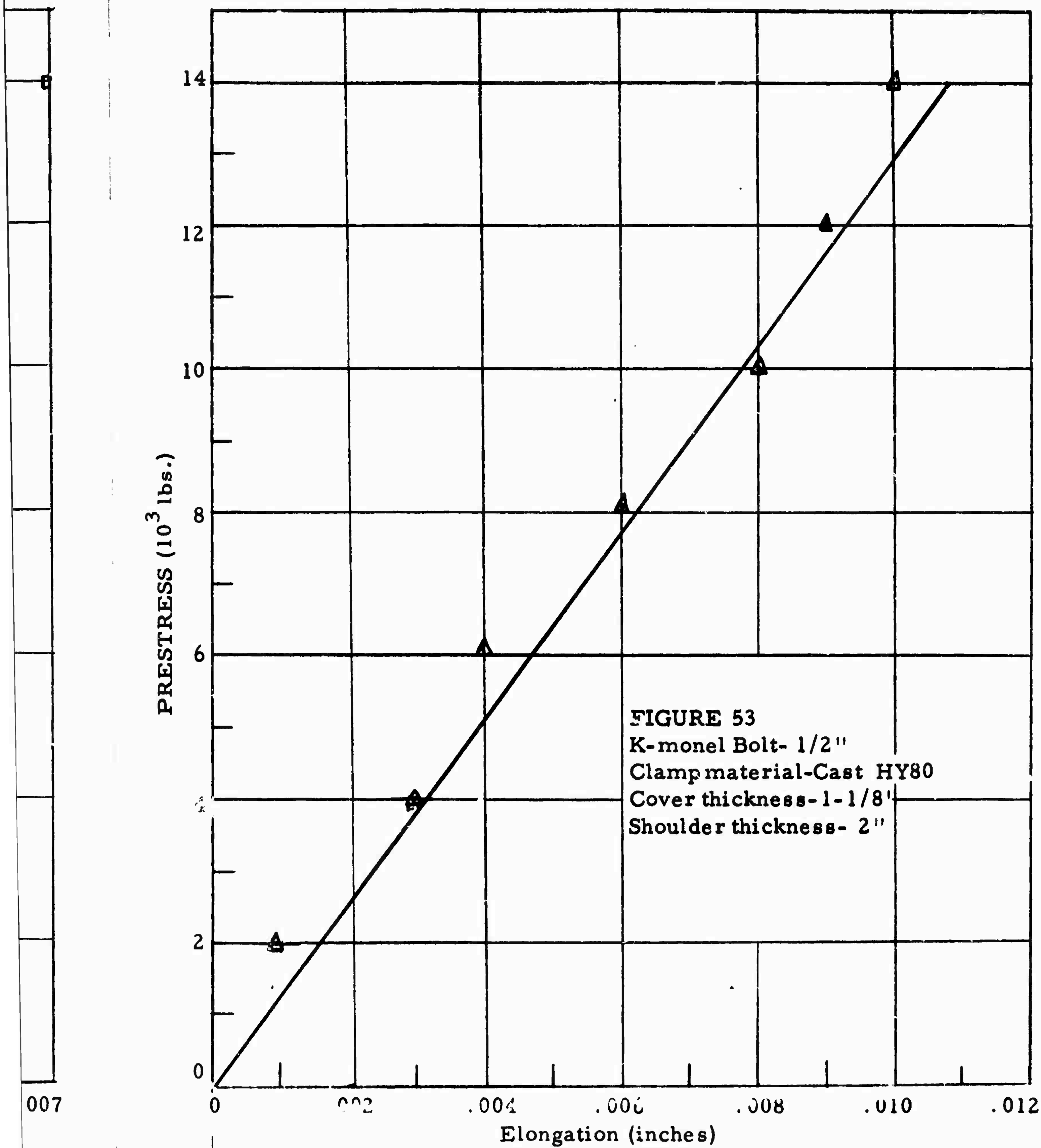


FIGURE 53
K-monel Bolt- 1/2"
Clamp material-Cast HY80
Cover thickness- 1-1/8"
Shoulder thickness- 2"
PRESTRESS (10^3 lbs.)
Elongation (inches)
0
2
6
8
10
12
14
0
.010
.012
007

VI DISCUSSION AND CONCLUSIONS

There are a number of factors which affect each of the three methods of measuring prestress, some of which are tabulated in Table IV.

Table IV Factor Affecting Prestress Methods

Factors Affecting Prestress Method	Prestress Method: Micrometer Method	Prestress Method: Torque Measurement Method	Prestress Method: Angular Turn of the Nut Method
Bolt or Stud Size	X	X	X
Bolt or Stud Length	X	X	X
Bolt or Stud Material	X	X	X
Threads per inch	-	X	X
Properties of Clamped Material	-	X	X
Type of Lubrication	-	X	-
Roughness of Bearing Surfaces	-	X	X
Roughness of the Threads	-	X	-
Type of Nut	-	X	-
Speed of Tightening	-	X	-
Type of Plating	-	X	X
Type of Washer	-	X	X
Type of Gasket	-	X	X
Deformation of Threads	-	X	X

Some of these factors were observed during the testing performed for this task and some are reported in the literature. It can be seen from this table that the Micrometer Method is affected only by the bolt size, design, length and material. The disadvantages of this method are that two points on the axis of the bolt must be accessible, these two ends of the bolt must be fairly smooth and parallel and it is difficult and, in many cases, impossible to determine at a later date if the initial prestress has been retained. Where two ends of a bolt are inaccessible or in the case of a stud, if the diameter is sufficiently large, an axial hole may be drilled in it and the change of depth of the hole determined with a micrometer

depth gage (see Handbook H28, Part III, page 53, Figure 12.2). Drilling of the hole increases cost. In addition, if the bolt or stud is not threaded its entire length or if the unthreaded shank does not have a cross sectional area equal to the equivalent tensile stress area of the threads, the depth of the hole drilled must be exactly the same for each bolt or stud used since the threaded and unthreaded portions will elongate differently. A better method than this one described in Handbook H28 for measuring elongation when two ends are inaccessible is to measure the elongation with reference to a fixed surface.

The Torque Measurement Method of determining prestress is affected by many factors as indicated in Table IV. Torque-tension results, therefore, are applicable only for the conditions used in the test. It was found that reproducibility of torque-tension data was excellent if conditions were kept constant. These data, however, could not be used if a washer or plating was used in service since these were not specified for use in the testing performed.

The Angular Turn of the Nut Method is affected by many of the same factors as the Torque Method although not by friction which accounts for about 90% of the torque in the Torque Method. In the tests performed, in addition to bolt or stud size, design, length and material which affects all three prestress methods, surface roughness of the clamped material seemed to affect angular turn of the nut. This was caused by the fact that turning the nut caused wear of the abutting clamped material so that some of the turn of the nut resulted in this wear rather than stretching of the bolt or stud. Since the amount of wear is affected by the degree of surface roughness, the amount the nut must be turned to achieve a desired prestress will vary with surface roughness. This could be greatly alleviated

by using a hardened washer where the surface roughness could be uniform from washer to washer so that there would be less wear because of the hardness and any wear that would occur would be uniform because of the uniform surface roughness.

The angular turn of the nut is affected by the clamp material for two reasons. First because of the difference in compressive strength and second because of the difference in the degree of wear among different materials which will affect angular turn data as described above. The amount of wear observed when clamping, say, valve bronze is much greater than that observed when clamping HY80 resulting in a greater number of turns for the valve bronze (see Figures 4, 5, and 6). The wear was so great for valve bronze for 1/2 inch studs that no tests were run with 7/8 and 1-1/8 inch studs since the higher prestress would have caused excessive wear to the point where the valve bronze could not be used. A hardened washer would eliminate this wear problem as described above.

In order for the Turn of the Nut Method to be reproducible, a suitable starting point for measuring the number of nut turns must be used. In the tests performed it was specified that measurement of the angular turn of the nut be started at a certain torque valve. The angular turn of the nut data were obtained in this manner by using the torque values on page 9 as the starting points. This is not a good starting point since from test to test this initial torque results in a slight prestress which could vary because of the conditions shown in Table IV. As an example, a certain 1/2 inch monel stud was used to clamp a two inch HY80 cover. Measurement of turn of the nut was begun at 120 in-lbs. The following are the results of two tests run under essentially the same conditions.

Turn of the Nut (degrees)		Tension
Test 1	Test 2	(lbs)
45	35	1000
59	50	2000
70	60	3000
80	69	4000
88	77	5000

The 120 in-lbs. used as a starting point resulted in a higher prestress for Test 2 so that to go from this initial prestress to 1000 lbs. prestress only required 35 degrees as compared to 45 degrees for Test 1. It can be seen, however, that the additional degrees of turns required to go from 1000 lbs. to any higher prestress is essentially the same for both tests. The angular turn of the nut data obtained in this task could be used, therefore, in the following manner. If a better method is found to start measuring turn of the nut and it is found that to obtain a preload of 1000 lbs. requires 20 degrees turn of the nut then to obtain a preload of 3000 lbs. you would go to the plot of Prestress vs. Turn of the Nut for the above data and observe that for both Tests 1 and 2, to go from 1000 lbs. prestress to 3000 lbs. requires 25 degrees turn of the nut. The turn of the nut necessary to obtain a preload of 3000 lbs., therefore, would be 20 + 25 or 45 degrees.

When engaging the self-locking nut on the stud or bolt it was found that the nut turned at a constant torque until a point where the wrench began to impact. This point might possibly be used as the starting point for measuring turn of the nut.

A further observation made was that after torquing materials such as valve bronze and cast HY80 to a high preload the induced load dropped after a short period of time.

APPENDIX

Monel Stud

Size: $\frac{1}{2}$" Clamp Material: HTS

Cover Thickness (inches) $\frac{9}{16}$

Turn of the Nut (degrees)	Torque (ft-lb)	Tension (lbs)
5	140"	1100
20	220"	2000
33	25'	3000
44	32'	4000
52	39'	5000

Monel Stud

Size: $\frac{1}{2}$" Clamp Material: HY80

Cover Thickness (inches) $\frac{9}{16}$

Turn of the Nut (degrees)	Torque (ft-lb)	Tension (lbs)
20	165"	1000
40	260"	2000
52	30	3100
60	35	4000
70	44	5000

Monel Stud

Size: $\frac{1}{2}$" Clamp Material: HTS

Cover Thickness (inches) $1\frac{1}{8}$

Turn of the Nut (degrees)	Torque (ft-lb)	Tension (lbs)
3	140"	1000
18	225"	2000
30	25	3000
36	33	4000
45	39	5000

Monel Stud

Size: $\frac{1}{2}$"   Clamp Material: HY80

Cover Thickness (inches) $1\frac{1}{8}$

Turn of the Nut (degrees)	Torque (ft-lb)	Tension (lbs)
15	170"	1300
22	223"	2000
35	24'	3000
40	32	4000
50	38	5000

Monel Stud

Size: $\frac{1}{2}$"   Clamp Material: HTS

Cover Thickness (inches) 2

Turn of the Nut (degrees)	Torque (ft-lb)	Tension (lbs)
20	190"	1300
33	255	2000
45	28	3000
54	36	4000
61	42	5000

Monel Stud

Size: $\frac{1}{2}$"   Clamp Material: HY80

Cover Thickness (inches) 2

Turn of the Nut (degrees)	Torque (ft-lb)	Tension (lbs)
10	12'	1000
22	21	2000
33	30	3000
43	34	4000
50	46	5000

K-Monel Stud

Size: $\frac{1}{2}$"   Clamp Material: HTS

Cover Thickness (inches) $\frac{9}{16}$

Turn of the Nut (degrees)	Torque (ft-lb)	Tension (lbs)
34	230"	2000
60	31	4000
75	42	6000
90	55	8000
105	66	10,000
120	75	12,000
135	86	14,000

K-Monel Stud

Size: $\frac{1}{2}$"   Clamp Material: HY80

Cover Thickness (inches) $\frac{9}{16}$

Turn of the Nut (degrees)	Torque (ft-lb)	Tension (lbs)
38	260"	2000
60	36	4000
80	50	6000
97	67	8000
114	76	10,000
130	86	12,000
145	97	14,000

K-Monel Stud

Size: $\frac{1}{2}$"   Clamp Material: HY80-Cast

Cover Thickness (inches) $\frac{9}{16}$

Turn of the Nut (degrees)	Torque (ft-lb)	Tension (lbs)
30	240"	2000
46	32	4000
65	47	6000
80	58	8000
97	75	10,000
112	88	12,000
127	100	14,000

K-Monel Stud

Size: $\frac{1}{2}$" Clamp Material: Monel

Cover Thickness (inches) $\frac{9}{16}$

Turn of the Nut (degrees)	Torque (ft-lb)	Tension (lbs)
30	255"	2000
58	40	4000
75	57	6000
90	72	8000
106	92	10,000
122	100	12,000
145	112	14,000

K-Monel Stud

Size: $\frac{1}{2}$" Clamp Material: Valve Bronze

Cover Thickness (inches) $\frac{9}{16}$

Turn of the Nut (degrees)	Torque (ft-lb)	Tension (lbs)
40	230"	2000
65	30	4000
90	43	6000
106	52	8000
135	64	10,000
155	74	12,000
180	87	14,000

K-Monel Stud

Size: $\frac{1}{2}$" Clamp Material: HTS

Cover Thickness (inches) $1\frac{1}{8}$

Turn of the Nut (degrees)	Torque (ft-lb)	Tension (lbs)
35	245"	2000
48	35'	4000
65	46'	6100
75	54'	8100
85	61	10,000
97	75	12,100
110	87	14,000

K-Monel Stud

Size: $\frac{1}{2}$"   Clamp Material: HY80

Cover Thickness (inches) $1\frac{1}{8}$

Turn of the Nut (degrees)	Torque (ft-lb)	Tension (lbs)
22	230"	2000
37	32'	4000
52	42	6000
66	53	8000
81	61	10,100
92	72	12,000
105	85	14,000

K-Monel Stud

Size: $\frac{1}{2}$"   Clamp Material: HY80-Cast

Cover Thickness (inches) $1\frac{1}{8}$

Turn of the Nut (degrees)	Torque (ft-lb)	Tension (lbs)
15	230"	2100
30	30	4000
45	44	6000
55	54	8000
67	69	10,000
80	83	12,000
91	95	14,000

K-Monel Stud

Size: $\frac{1}{2}$"   Clamp Material: Monel

Cover Thickness (inches) $1\frac{1}{8}$

Turn of the Nut (degrees)	Torque (ft-lb)	Tension (lbs)
22	250"	2100
44	33	4000
55	48	6000
67	59	8000
81	72	10,000
95	88	12,000
108	98	14,000

K-Monel Stud

Size: $\frac{1}{2}$" Clamp Material: Valve Bronze

Cover Thickness (inches) $1\frac{1}{8}$

Turn of the Nut (degrees)	Torque (ft-lb)	Tension (lbs)
40	260"	2000
60	35'	4000
75	44	6000
90	57	8000
105	69	10,000
125	78	12,000
140	90	14,000

K-Monel Stud

Size: $\frac{1}{2}$" Clamp Material: HTS

Cover Thickness (inches) 2

Turn of the Nut (degrees)	Torque (ft-lb)	Tension (lbs)
20	225"	2000
40	35	4100
55	49	6000
67	63	8000
85	71	10,100
100	79	12,000
112	89	14,000

K-Monel Stud

Size: $\frac{1}{2}$" Clamp Material: HY80

Cover Thickness (inches) 2

Turn of the Nut (degrees)	Torque (ft-lb)	Tension (lbs)
35	280"	2000
58	38	4000
70	56	6250
83	66	8000
97	81	10,100
110	94	12,000
125	104	14,100

K-Monel Stud

Size: ½"   Clamp Material: HY80-Cast

Cover Thickness (inches) 2

Turn of the Nut (degrees)	Torque (ft-lb)	Tension (lbs)
25	270"	2000
45	38	4000
60	55	6000
73	67	8000
85	75	10,000
97	86	12,100
111	97	14,000

K-Monel Stud

Size: ½"   Clamp Material: Monel

Cover Thickness (inches) 2

Turn of the Nut (degrees)	Torque (ft-lbs)	Tension (lbs)
30	230"	2000
52	31	4000
69	45	6000
85	53	8100
100	68	10,100
115	78	12,000
130	89	14,000

K-Monel Stud

Size: ½"   Clamp Material: Valve Bronze

Cover Thickness (inches) 2

Turn of the Nut (degrees)	Torque (ft-lb)	Tension (lbs)
30	210"	2000
60	28	4000
82	42	6000
100	55	8000
127	69	10,000
150	77	12,000
187	91	14,000

Monel Bolt

Size: $\frac{1}{2}$ " Clamp Material: HTS

Shoulder Thickness (inches) $\frac{9}{16}$ Cover Thickness (inches) $\frac{9}{16}$

Turn of the Nut (degrees)	Torque (ft-lb)	Tension (lbs)
10	158" [1]	1000
30	250"	2000
45	27	3000
59	35	4000
76	42	4900
110	48	6000
180	60	7000

[1] in.-lb.

Monel Bolt

Size: $\frac{1}{2}$ " Clamp Material: HY80

Shoulder Thickness (inches) $\frac{9}{16}$ Cover Thickness (inches) $\frac{9}{16}$

Turn of the Nut (degrees)	Torque (ft-lb)	Tension (lbs)
14	160"	1000
30	255"	2000
43	29	3000
52	37	4000
60	44	5000

Monel Bolt

Size: $\frac{1}{2}$"   Clamp Material: HTS

Shoulder Thickness (inches) 2   Cover Thickness (inches) $1\frac{1}{8}$

Turn of the Nut (degrees)	Torque (ft-lb)	Tension (lbs)
17	165"	1000
30	255"	2000
48	29'	3000
60	35'	4000
75	44	5000
100	55	6000

Monel Bolt

Size: $\frac{1}{2}$"   Clamp Material: HY80

Shoulder Thickness (inches) 2   Cover Thickness (inches) $1\frac{1}{8}$

Turn of the Nut (degrees)	Torque (ft-lb)	Tension (lbs)
14	140"	1000
31	215"	2000
45	24'	3000
57	30'	4000
70	37	5000

K-Monel Bolt

Size: $\frac{1}{2}$"   Clamp Material: HTS

Shoulder Thickness (inches) $\frac{9}{16}$ Cover Thickness (inches) $\frac{9}{16}$

Turn of the Nut (degrees)	Torque (ft-lb)	Tension (lbs)
22	205"	2000
45	29	4100
60	42	6100
75	53	8000
92	65	10,000
110	75	12,000
125	87	14,000

K-Monel Bolt

Size: $\frac{1}{2}$" Clamp Material: HY80

Shoulder Thickness (inches) $\frac{9}{16}$ Cover Thickness (inches) $\frac{9}{16}$

Turn of the Nut (degrees)	Torque (ft-lb)	Tension (lbs)
29	250"	2000
52	32	4000
67	45	6100
86	59	8100
101	69	10,000
115	81	12,000
132	90	14,000

K-Monel Bolt

Size: $\frac{1}{2}$" Clamp Material: HY80 Cast

Shoulder Thickness (inches) $\frac{9}{16}$ Cover Thickness (inches) $\frac{9}{16}$

Turn of the Nut (degrees)	Torque (ft-lb)	Tension (lbs)
30	210"	2000
50	28 ft/lb	4000
70	45 ft/lb	6000
87	53	8000
103	68	10,000
115	77	12,000
135	89	14,000

K-Monel Bolt

Size: $\frac{1}{2}$" Clamp Material: Monel

Shoulder Thickness (inches) $\frac{9}{16}$ Cover Thickness (inches) $\frac{9}{16}$

Turn of the Nut (degrees)	Torque (ft-lb)	Tension (lbs)
26	235"	2000
47	32	4000
67	45	6000
83	57	8000
98	67	10,000
113	79	12,000
135	89	14,000

K-Monel Bolt

Size: $\frac{1}{2}$" Clamp Material: Valve Bronze

Shoulder Thickness (inches) $\frac{9}{16}$ Cover Thickness (inches) $\frac{9}{16}$

Turn of the Nut (degrees)	Torque (ft-lb)	Tension (lbs)
44	245"	2000
76	34	4000
115	45	6000
165	56	8000
227	69	10,000
300	86	12,000
395	115	14,000

K-Monel Bolt

Size: $\frac{1}{2}$" Clamp Material: HTS

Shoulder Thickness (inches) 2 Cover Thickness (inches) $1\frac{1}{8}$

Turn of the Nut (degrees)	Torque (ft-lb)	Tension (lbs)
30	275"	2000
53	40	4100
70	58	6000
85	70	8000
101	87	10,000
117	100	12,000
135	110	14,000

K-Monel Bolt

Size: $\frac{1}{2}$" Clamp Material: HY80

Shoulder Thickness (inches) 2 Cover Thickness (inches) $1\frac{1}{8}$

Turn of the Nut (degrees)	Torque (ft-lb)	Tension (lbs)
30	235"	2000
43	25	3000
52	32	‘100
71	47	6000
87	58	8000
105	69	10,000
120	78	12,000
137	88	14,000

K-Monel Bolt

Size: $\frac{1}{2}$"   Clamp Material: HY80 Cast

Shoulder Thickness (inches) 2   Cover Thickness (inches) $1\frac{1}{8}$

Turn of the Nut (degrees)	Torque (ft-lb)	Tension (lbs)
30	232"	2000
58	35	4000
81	50	6100
102	67	8100
120	80	10,000
140	98	12,000
162	110	14,000

K-Monel Bolt

Size: $\frac{1}{2}$"   Clamp Material: Monel

Shoulder Thickness (inches) 2   Cover Thickness (inches) $1\frac{1}{8}$

Turn of the Nut (degrees)	Torque (ft-lb)	Tension (lbs)
36	280"	2000
61	40	4100
85	58	6000
105	71	8000
127	90	10,100
150	107	12,000
172	120	14,000

K-Monel Bolt

Size: $\frac{1}{2}$"   Clamp Material: Valve Bronze

Shoulder Thickness (inches) 2   Cover Thickness (inches) $1\frac{1}{8}$

Turn of the Nut (degrees)	Torque (ft-lb)	Tension (lbs)
32	222"	2000
70	31	4000
100	44	6000
133	60	8000
180	71	10,000
225	83	12,000
271	94	14,000

Size: 7/8 " Clamp Material: HTS

Cover Thickness (inches) 1-1/8

Turn of the Nut (degrees)	Torque (ft-lb)	Tension (lbs)
25	83	5000
30	108	7000
35	135	9000
41	162	11,000
46	190	13,100
50	216	15,100
52	226	16,000

Monel Stud

Size: 7/8 " Clamp Material: HY80

Cover Thickness (inches) 1-1/8

Turn of the Nut (degrees)	Torque (ft-lb)	Tension (lbs)
20	55	2000
33	92	4000
45	119	6000
48	144	8000
55	165	10,000
58	190	12,000
62	216	14,000
66	241	16,000

Monel Stud

Size: 7/8 " Clamp Material HTS

Cover Thickness (inches) 2

Turn of the Nut (degrees)	Torque (ft-lb)	Tension (lbs)
22	50	2000
52	95	4000
67	110	6000
77	140	8000
90	163	10,000
97	188	12,000
103	240	14,250
110	264	16,000

Size: 7/8 " Clamp Material: HY80

Cover Thickness (inches) 2

Turn of the Nut (degrees)	Torque (ft-lb)	Tension (lbs)
22	53	3000
33	68	5000
45	100	7000
55	125	9000
61	145	11,000
70	170	13,000
76	192	15,000
80	208	16,000

K-Monel Stud

Size: 7/8 " Clamp Material: HTS

Cover Thickness (inches) 1-1/8

Turn of the Nut (degrees)	Torque (ft-lb)	Tension (lbs)
22	90	5300
32	160	10,000
45	220	15,000
55	280	20,000
63	328	25,000
75	392	30,000
85	412	35,000
93	440	40,000

K-Monel Stud

Size: 7/8 " Clamp Material: HY80

Cover Thickness (inches) 1-1/8

Turn of the Nut (degrees)	Torque (ft-lb)	Tension (lbs)
65	90	5000
93	152	10,000
115	225	15,100
127	326	20,000
140	400	25,000
150	472	30,000
160	524	35,000
172	568	40,000

Size: 7/8 " Clamp Material: HY80- Cast

Cover Thickness (inches) 1-1/8

Turn of the Nut (degrees)	Torque (ft-lb)	Tension (lbs)
50	100	5000
78	145	10,000
97	220	15,250
110	300	20,100
120	348	25,000
132	420	30,000
142	480	35,000
153	552	40,000

K-Monel Stud

Size: 7/8 " Clamp Material: Monel

Cover Thickness (inches) 1-1/8

Turn of the Nut (degrees)	Torque (ft-lb)	Tension (lbs)
65	100	5000
85	185	10,000
100	240	15,000
112	300	20,000
127	440	25,500
138	500	30,000
152	560	35,000
167	632	40,000

K-Monel Stud

Size: 7/8 " Clamp Material: Valve Bronze

Cover Thickness (inches) 1-1/8

Turn of the Nut (degrees)	Torque (ft-lb)	Tension (lbs)
47	87	5000
75	160	10,000
91	244	15,000
120	320	20,000
152	392	25,000
190	462	30,000
250	520	35,000
340	660	40,000

K-Monel Stud

Size: 7/8 " Clamp Material: HTS

Cover Thickness (inches) 2

Turn of the Nut (degrees)	Torque (ft-lb)	Tension (lbs)
15	80	5000
35	140	10,300
46	199	15,000
60	268	20,000
75	340	25,000
80	364	30,000
108	408	35,000
140	456	40,000

K-Monel Stud

Size: 7/8 " Clamp Material: HY80

Cover Thickness (inches) 2

Turn of the Nut (degrees)	Torque (ft-lb)	Tension (lbs)
5	40	2000
20	68	4000
31	91	6000
42	118	8000
51	148	10,000
59	196	12,000
65	216	14,000
70	240	16,000
81	280	20,000
92	348	25,000
105	400	30,000
116	480	35,000
130	540	40,000

K-Monel Stud

Size: 7/8 " Clamp Material: HY80-Cast

Cover Thickness (inches) 2

Turn of the Nut (degrees)	Torque (ft-lb)	Tension (lbs)
25	81	5000
37	148	10,250
49	232	15,000
60	300	20,000
71	360	25,000
80	432	30,000
92	480	35,000
108	520	40,000

K-Monel Stud

Size: 7/8 " Clamp Material: Monel

Cover Thickness (inches) 2

Turn of the Nut (degrees)	Torque (ft-lb)	Tension (lbs)
45	80	5000
75	155	10,000
100	280	15,000
115	320	20,000
136	412	25,000
155	480	30,000

Monel Bolt

Size: 7/8 " Clamp Material: HTS

Shoulder Thickness (inches) 1-1/8 Cover Thickness (inches) 1-1/8

Turn of the Nut (degrees)	Torque (ft-lb)	Tension (lbs)
16	39	2000
24	70	4000
32	90	6000
40	119	8000
47	140	10,000
52	179	12,250
57	210	14,100
63	235	16,200

Monel Bolt

Size: 7/8 " Clamp M terial: HY80

Shoulder Thickness (inches) 1-1/8 Cover Thickness (inches) 1-i/8

Turn of the Nut (degrees)	Torque (ft-lb)	Tension (lbs)
15	38	2000
28	70	4000
33	94	6100
40	120	8000
45	148	10,000
51	180	12,250
58	210	14,000
61	244	16,000
67	278	18,000
75	360	20,000
88	400	22,000

Monel Bolt

Size: 7/8 " Clamp Material: HTS

Shoulder Thickness (inches) 2 Cover Thickness (inches) 9/16

Turn of the Nut (degrees)	Torque (ft-lb)	Tension (lbs)
14	38	2000
29	60	4000
37	97	5250
45	120	8000
55	146	10,300
61	168	12,000
68	195	14,000
76	224	16,000

Monel Bolt

Size: 7/8 " Clamp Material: HY80

Shoulder Thickness (inches) 2 Cover Thickness (inches) 9/16

Turn of the Nut (degrees)	Torque (ft-lb)	Tension (lbs)
19	36	2000
31	66	4000
41	90	6000
51	114	8000
60	130	10,250
67	155	12,000
75	185	14,100
83	248	16,000

K-Monel Bolt

Size: 7/8 " Clamp Material: HTS

Shoulder Thickness (inches) 1-1/8 Cover Thickness (inches) 1-1/8

Turn of the Nut (degrees)	Torque (ft-lb)	Tension (lbs)
20	70	5200
37	138	10,000
48	218	15,100
60	332	20,000
75	380	25,000
88	410	30,000
102	464	35,000
125	520	40,000
132	568	45,000

K-Monel Bolt

Size: 7/8 " Clamp Material: HY80

Shoulder Thickness (inches) 1-1/8 Cover Thickness (inches) 1-1/8

Turn of the Nut (degrees)	Torque (ft-lb)	Tension (lbs)
46	90	5000
60	142	10,000
76	190	14,900
93	253	21,000
103	340	25,000
110	372	30,000
125	432	35,000
138	500	40,000
150	528	45,000
170	588	50,000
210	620	55,000

K-Monel Bolt

Size: 7/8 " Clamp Material: HY80 Cast

Shoulder Thickness (inches) 1-1/8 Cover Thickness (inches) 1-1/8

Turn of the Nut (degrees)	Torque (ft-lb)	Tension (lbs)
32	90	5000
45	165	10,250
58	240	15,000
70	400	20,000
82	440	25,000
95	492	30,000
107	560	35,100
120	624	40,000

K-Monel Bolt

Size: 7/8 " Clamp Material: Monel

Shoulder Thickness (inches) 1-1/8 Cover Thickness (inches) 1-1/8

Turn of the Nut (degrees)	Torque (ft-lb)	Tension (lbs)
30	75	5000
53	155	10,[illegible]
71	252	15,000
92	377	20,000
112	436	25,000
127	528	30,000
150	692	35,000
172	792	40,000

K-Monel Bolt

Size: 7/8 " Clamp Material: HTS

Shoulder Thickness (inches) 2 Cover Thickness (inches) 9/16

Turn of the Nut (degrees)	Torque (ft-lb)	Tension (lbs)
35	73	5500
55	115	10,700
72	202	15,000
93	292	20,000
118	368	25,000
145	400	30,000
205	494	35,000
295	560	39,000

K-Monel Bolt

Size: 7/8 " Clamp Material: HY80

Shoulder Thickness (inches) 2 Cover Thickness (inches) 9/16

Turn of the Nut (degrees)	Torque (ft-lb)	Tension (lbs)
37	68	4000
75	150	10,000
97	215	15,000
115	324	20,000
135	420	25,000
152	468	30,000
168	548	35,000
187	600	40,000

K-Monel Bolt

Size: 7/8 " Clamp Material: HY80-Cast

Shoulder Thickness (inches) 2 Cover Thickness (inches) 9/16

Turn of the Nut (degrees)	Torque (ft-lb)	Tension (lbs)
45	97	5250
67	173	10,100
92	260	15,000
110	340	20,000
130	400	25,000
152	460	30,000
175	508	35,000
205	560	40,000
237	592	45,000

K-Monel Bolt

Size: 7/8 " Clamp Material: Monel

Shoulder Thickness (inches) 2 Cover Thickness (inches) 9/16

Turn of the Nut (degrees)	Torque (ft-lb)	Tension (lbs)
37	95	5000
58	174	10,000
82	272	15,000
120	376	20,000
175	468	25,000
232	560	30,000
307	600	35,000
457	720	40,000

Monel Stud

Size: 1-1/8 " Clamp Material: HTS

Cover Thickness (inches) 1-1/8

Turn of the Nut (degrees)	Torque (ft-lb)	Tension (lbs)
29.4	151	5000
51.8	300	11,000
61	472	15,100
70.2	568	20,000
78.4	712	25,000
83.4	880	30,500
89.6	1008	35,000
96.6	1080	40,000

Monel Stud

Size: 1-1/8 " Clamp Material: HY80

Cover Thickness (inches) 1-1/8

Turn of the Nut (degrees)	Torque (ft-lb)	Tension (lbs)
22.4	150	5000
33.6	300	10,000
44.8	420	15,000
57	600	20,000
68.2	680	25,000
76	820	31,000
83.4	940	35,000
91.6	1040	40,000

Monel Stud

Size: 1-1/8 " Clamp Material: HTS

Cover Thickness (inches) 2

Turn of the Nut (degrees)	Torque (ft-lb)	Tension (lbs)
27.4	200	5000
39.6	360	10,000
48.8	480	15,000
58	568	20,300
67.2	680	25,000
73.2	760	30,000
78.4	860	35,000
84.8	968	40,000
95.6	1060	45,000
121	1200	47,300

Monel Stud

Size: 1-1/8 " Clamp Material: HY80

Cover Thickness (inches) 2

Turn of the Nut (degrees)	Torque (ft-lb)	Tension (lbs)
39.6	142	5000
56	260	10,300
67.2	416	15,000
76	520	20,000
82.4	620	25,000
89.6	780	31,000
95.6	864	35,400
102.8	1008	40,700

K-Monel Stud

Size: 1-1/8 " Clamp Material: HTS

Cover Thickness (inches) 1-1/8

Turn of the Nut (degrees)	Torque (ft-lb)	Tension (lbs)
28.4	165	8400
44.8	320	16,250
57	500	24,000
69.2	668	32,000
78.4	860	40,500
89.6	1040	49,000
98	1140	56,000

K-Monel Stud

Size: 1-1/8 " Clamp Material: HY80

Cover Thickness (inches) 1-1/8

Turn of the Nut (degrees)	Torque (ft-lb)	Tension (lbs)
30.6	172	8000
53	392	16,400
67.2	560	24,750
78.4	760	32,000
86.4	900	40,000
97.6	1100	48,300

K-Monel Stud

Size: 1-1/8 " Clamp Material: HY80-Cast

Cover Thickness (inches) 1-1/8

Turn of the Nut (degrees)	Torque (ft-lb)	Tension (lbs)
43.8	190	8100
58	360	16,100
72.2	572	24,000
80.4	728	32,000
89.6	964	40,000
98	1040	48,000
104.8	1200	54,000

K-Monel Stud

Size: 1-1/8 " Clamp Material: Monel

Cover Thickness (inches) 1-1/8

Turn of the Nut (degrees)	Torque (ft-lb)	Tension (lbs)
22.4	210	8100
35.6	432	16,000
54	620	24,000
67.2	832	32,000
74	1052	40,500
89.6	1200	47,500

K-Monel Stud

Size: 1-1/8 " Clamp Material: HTS

Cover Thickness (inches) 2

Turn of the Nut (degrees)	Torque (ft-lb)	Tension (lbs)
33.6	160	8000
56	336	16,000
58.2	484	23,750
78.4	620	32,700
89	692	40,000
95	832	48,500
105.8	920	55,900
119.2	1120	64,000

K-Monel Stud

Size: 1-1/8 " Clamp Material: HY80

Cover Thickness (inches) 2

Turn of the Nut (degrees)	Torque (ft-lb)	Tension (lbs)
30.4	175	8000
46.8	380	16,100
62	580	24,000
73.2	760	33,300
81.4	860	41,000
90.6	1020	49,000
99.8	1180	56,000

K-Monel Stud

Size: 1-1/8 "   Clamp Material: HY80-Cast

Cover Thickness (inches) 2

Turn of the Nut (degrees)	Torque (ft-lb)	Tension (lbs)
44.8	240	8250
67.2	600	16,250
78.4	760	24,000
88	876	33,500
94.6	980	40,000
100	1200	45,800

K-Monel Stud

Size: 1-1/8 "   Clamp Material: Monel

Cover Thickness (inches) 2

Turn of the Nut (degrees)	Torque (ft-lb)	Tension (lbs)
33	180	8000
56	400	16,000
70.2	592	24,500
81.4	760	32,000
90.6	952	40,000
103.8	1100	47,500

Monel Bolt

Size: 1-1/8 " Clamp Material: HTS

Shoulder Thickness (inches) 1-1/8 Cover Thickness (inches) 1-1/8

Turn of the Nut (degrees)	Torque (ft-lb)	Tension (lbs)
22.4	163	4000
34.6	256	8250
46	388	12,000
58	520	16,250
66.2	672	20,000
71.2	760	24,000
88	940	29,000

Monel Bolt

Size: 1-1/8 " Clamp Material: HY80

Shoulder Thickness (inches) 1-1/8 Cover Thickness (inches) 1-1/8

Turn of the Nut (degrees)	Torque (ft-lb)	Tension (lbs)
28.2	195	5000
44	340	10,250
56	496	15,000
80.4	648	20,100
123.2	832	24,750

K-Monel Bolt

Size: 1-1/8 " Clamp Material: HTS

Shoulder Thickness (inches) 1-1/8 Cover Thickness (inches) 1-1/8

Turn of the Nut (degrees)	Torque (ft-lb)	Tension (lbs)
58	245	10,250
72.2	364	16,000
86.4	532	24,000
94.6	640	30,000
110	808	40,000
123.2	946	48,000
143	980	55,000
151	1088	60,000

K-Monel Bolt

Size: 1-1/8 " Clamp Material: HY80

Shoulder Thickness (inches) 1-1/8 Cover Thickness (inches) 1-1/8

Turn of the Nut (degrees)	Torque (ft-lb)	Tension (lbs)
38.6	150	8000
66.2	280	16,000
78.4	440	24,000
89.6	592	32,500
100.8	680	40,000
112	823	48,500
131.2	940	57,500
135.4	1060	60,000

K-Monel Bolt

Size: 1-1/8 " Clamp Material: HY80-Cast

Shoulder Thickness (inches) 1-1/8 Cover Thickness (inches) 1-1/8

Turn of the Nut (degrees)	Torque (ft-lb)	Tension (lbs)
30.2	167	8100
49.8	352	16,100
67.2	576	24,100
78.4	732	32,100
89.6	888	40,000
100.8	1080	48,000

K-Monel Bolt

Size: 1-1/8 " Clamp Material: Monel

Shoulder Thickness (inches) 1-1/8 Cover Thickness (inches) 1-1/8

Turn of the Nut (degrees)	Torque (ft-lb)	Tension (lbs)
37.6	250	8500
58	512	16,000
78.4	680	24,250
92.6	920	32,000
107.8	1120	40,000